Cranfield University

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Climate Proofing Water and Sanitation Services and Applying Integrated Water Resource Management in Slums

School of Applied Sciences

Master of Science by Research

Cranfield University

School of Applied Science

MSc (Res) THESIS

2011

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Academic Year 2010 to 2011

This thesis is submitted in fulfilment of the requirements for the degree of MSc (Res)

Abstract

This thesis assesses how climate change impacts water resources and communities and reviews how the resource can be managed in an integrated manner for small water and sanitation providers. This thesis was based upon a 10 month Knowledge Transfer Partnership (KTP) between Cranfield University and Water and Sanitation for the Urban Poor (WSUP). The aim of the project was to assess the opportunities and vulnerabilities presented by climate change and how Integrated Water Resource Management (IWRM) is relevant to water and sanitation services for the urban poor. This thesis is based on two papers prepared following the KTP. The research was based upon a literature review and field work to WSUP projects in Lusaka (Zambia), Naivasha (Kenya) and Antananarivo (Madagascar). During the field work 11 focus groups and 97 stakeholder interviews were completed, in addition direct observation was undertaken throughout. To assess the impact of climate change a vulnerability assessment methodology was developed consisting of a vulnerability assessment, reviewing climate predictions, preparing hydrology scenairios and identify adaptations. In the three cities assessed, eleven communities were visited of which eight were vulnerable to flooding and four to water shortages. The research indicated that for water and sanitation providers climate change will tend to exacerbate or relieve existing vulnerabilities rather than create new issues and to adapt, water and sanitation providers need to increase the robustness of their systems by assessing the impacts across multiple scenarios. To assess the relevance of IWRM a literature review was undertaken and a benchmarking process developed based around the main principles of IWRM and fieldwork in Zambia. The IWRM assessment found that IWRM is generally irrelevant to water and sanitation suppliers to the urban poor.

Acknowledgments

I would like to express sincere thanks to all of the individuals who generously gave their time in interviews and focus groups. I would like to thank the WSUP staff in Zambia, Kenya and Madagascar for their invaluable support during the field work. In addition, I would like to thank the Madagascan team for being such generous and friendly hosts, assisting with translation, transport, accommodation and food. I would also like to thank James Phiri for his support during my fieldwork in Lusaka.

Special thanks to Water and Sanitation for the Urban Poor (WSUP) and Knowledge Transfer Partnership for funding the project and specifically Tim Hayward and Sam Parker for their dedicated support and insight, ensuring the project was relevant and pragmatic. I would also like to thank Patricia Schelle and Richard Wilson for their thorough feedback.

I'm extremely thankful for Alison Parker's continuous engagement, critiques and patience. Likewise, I'm very grateful to Keith Weatherhead for always maintaining a bigger picture of the project and identifying key questions at the right times. Finally I would like to thank my wife Kate Heath for your proof reading, endless enthusiasm and support throughout the project, in particular, your baking.

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Acronyms

GWP	Global Water Partnership
IWRM	Integrated Water Resource Management
KTP	Knowledge Transfer Partnership
SWOT	Strengths, Weakness, Opportunities and Threats
WSUP	Water and Sanitation for the Urban Poor

1 Overview

1.1 Aims

This thesis was based upon research undertaken during and following a 10 month Knowledge Transfer Partnership (KTP) between Water and Sanitation for the Urban Poor (WSUP) and Cranfield University. The aim established by WSUP and Cranfield for the KTP was:

To assess the vulnerabilities and opportunities presented by climate change and determine how IWRM principles will be best used by WSUP projects

This was then was divided into the following objectives:

1. To produce pragmatic guidelines, to make water and sanitation for the urban poor climate resilient. The guidelines are aimed at three key players:
   - Local Service Providers
   - Water Utilities
   - Local Municipalities
2. To summarise the impacts of climate change and how WSUP should incorporate climate into future work
3. To assess the relevance of IWRM to WSUP projects

Based on these aims reports were prepared for three case studies for WSUP which are presented in the appendix. This work was then used to develop two papers, which are:

- Climate Proofing Water and Sanitation for the Urban Poor
- The Relevance of Integrated Water Resource Management to Water Providers in Urban Slums in Developing Countries: Examples from Zambia

1.2 Background to Water and Sanitation for the Urban Poor

WSUP are a partnership between public, private and civil society organisations, and operates as a not-for-profit company. WSUP's mission is to improve the lives of the urban poor in developing countries by strengthening the capacity of local service providers and others to provide sustainable water and sanitation services, promote good hygiene and raise the health and environmental standards of the community. They focus upon capacity building local service providers to supply water and sanitation services and work with the service users to ensure the services are acceptable. When no local partners are available they work as the local implementer. They work with the urban poor in 9 projects across 8 developing countries. WSUP funded the project through a Knowledge Transfer Partnership with Cranfield University and the reports in the appendix were prepared for WSUP.

1.3 Method

The project was based on three case studies, Lusaka (Zambia), Naivasha (Kenya) and Antananarivo (Madagascar). The case studies were selected from the 9 cities WSUP works in. Case studies were chosen with WSUP and Cranfield University based on a discussion of climate, logistics, and security issues. Before the first field visit a literature review on IWRM and climate change was undertaken (Appendix A). Pilot methodologies were then developed to assess the impacts of climate change and relevance of IWRM to WSUP. Lusaka was used as a pilot study to test the climate and IWRM methodologies. Before the field visit a brief summary of the impacts of climate change on Zambia was prepared (Appendix B). The climate methodology consists of establishing the predicted changes to climate, the impacts on the country and the project's vulnerability to floods and droughts. This information was used as the basis for developing a range of climate change scenarios, assessing the potential impacts on each project and its hydrology. Adaptations were then identified to climate proof water and sanitation services for the local service provider, water utility and local municipality. The IWRM methodology consisted of semi-structured questions based around the principles of IWRM. Table 1 identifies the strengths and weakness of the climate change and IWRM methodology.

Table 1 Strengths and Weakness of the climate change and IWRM methodology

	Strengths	Weakness
Climate Change Methodology	– Identifies specific local adaptations based on regional modelling – Assesses the hydrology – Can be done qualitatively with minimal data – Can be done in country by local organisation – Incorporates uncertainty	– Uncertainties associated with climate modelling, physics and scenarios make it difficult to quantify the climate changes for a country (even greater at the city scale) – Difficult developing accurate hydrology scenarios due to uncertainties with runoff and recharge – Lack of detail in assessments means not able to provide detailed specifications for adaptations
IWRM Methodology	– Provides a benchmarking process – Identifies the key principles of IWRM – Simple process to undertake – Can be done in country by local organisation	– Focused upon local level and doesn't engage with policy aspects – Limited gauge of collaboration or participation

The field work in Lusaka was for 2 weeks and was based on two peri-urban areas - Chazanga and Kanyama and consisted of semi-structured interviews. After the field visit a climate proofing report was prepared for Lusaka (Appendix C). This outlined the impacts of climate change on the peri-urban areas and recommended adaptations for the local service provider, utility and municipality. The project focused upon climate change once the Lusaka work was finished. The climate change methodology was then applied to Kenya and Madagascar. For each case study a brief summary of the impacts of climate change on the country was prepared (Appendix D, F) and then distributed during the field visits. Each field visit lasted 2 weeks and consisted of semi-structured interviews and focus groups. More details on the methods for the three case studies are provided in the papers and reports. Following the field trip a report was prepared for each city, outlining the impacts of climate change on the areas WSUP works in and recommending adaptations for the local service provider, utility and municipality (Appendix E,G).

The dates of the field work were as follows:

- Lusaka, Zambia: May 2010
- Naivasha, Kenya: July - August 2010
- Antananarivo, Madagascar: August – September 2010

Following the case studies a summary report was written, overviewing how WSUP should account for climate change (Appendix H). A policy brief, summarizing the relevance of IWRM to WSUP (Appendix I), and a Terms of Reference for the climate proofing work was also prepared (Appendix J). The Terms of reference outlines the methodology for the climate proofing reports, including the resources and staffing requirements. The final component of the project was preparing a concept note for WSUP to assist in raising future funding for climate proofing work (Appendix K). Table 2 overviews the reports produce for WSUP during the KTP. The reports are listed in the Appendix in the same order.

Table 2 Overview of reports produced for WSUP during KTP

Ob.	Title	Aim	Content	Date Complete	Page Count
3	Pragmatic but Principled: Background report on IWRM	Literature review of the relevance of IWRM to WSUP	Overview of IWRM background, implementation, experience, relevance to water and sanitation, urban areas and developing countries, outline of the future of IWRM and the relevance to WSUP	Apr 2010	19
1	Zambia Climate Change Briefing	Overview of the predicted changes to climate in Zambia	Predicted changes to climate, impacts of the change, importance of climate, vulnerability to climate change and impacts on Lusaka	Apr 2010	4
1	How to climate proof water and sanitation services in the peri-urban areas in Lusaka	Overview of how WSUP projects in Lusaka will be affected by climate change and how to adapt	Impact of climate change on water resources and project, recommendations for local service provider, utility and local municipality	Jun 2010	42
1	Kenya Climate Change Briefing	Overview of the predicted changes to climate in Kenya	Predicted changes to climate, impacts of the change, importance of climate, vulnerability to climate change and overview of water resources	Jul 2010	4
1	How to climate proof water and sanitation services in the peri-urban areas in Naivasha	Overview of how WSUP projects in Naivasha will be affected by climate change and how to adapt	Impact of climate change on water resources and project, recommendations for local service provider, utility and local municipality	Aug 2010	38

1	Madagascar Climate Change Briefing	Overview of the predicted changes to climate in Madagascar	Predicted changes to climate, impacts of the change, importance of climate, vulnerability to climate change and overview of water resources	Aug 2010	4
1	How to climate proof water and sanitation services in the informal areas and peri-urban areas in Antananarivo.	Overview of how WSUP projects in Antananarivo will be affected by climate change and how to adapt	Impact of climate change on water resources, project, and existing plans, recommendations for local service providers, utility and local municipality, further information	Sep 2010	35
2	How to Climate Proof Water & Sanitation Services for the Urban Poor	Summary of the impacts of climate change on WASH and how to adapt	Climate change science, impact on water and sanitation services, relevance of climate change, how to adapt and key references	Oct 2010	12
3	IWRM Policy Brief	Relevance of IWRM to WSUP	Overview of IWRM, situations when it is relevant to WSUP and situations when it is not	Oct 2010	2
2	Terms of Reference Climate proofing Assessment	Terms of reference for consultant to undertake climate proofing reports	Background to project, objective of work, proposed objectives, overview of methodology, staffing and deliverables	Oct 2010	4
2	Funding Concept Note: Climate Proofing Water and Sanitation Services	Outline for a funding proposal to improve the environmental resilience of WSUP projects	Background to project, specific objectives and proposed activities for proposal and overview of city specific activities	Nov 2010	5

1.4 Research Findings

The climate study applied the climate methodology to each case study developing adaptations for each. Based upon the case studies it was evident the communities were more vulnerable to extreme events than gradual changes in climate. In the three cities assessed, eleven communities were visited of which eight were vulnerable to flooding and four to water shortages. The impacts of climate change upon areas at risk to flooding and drought were very similar across all three cities and can be divided into regional and local scales. Common adaptations were developed for these risks for the local service provider, water utilities and municipality for floods and droughts. The research also highlighted the limited climate awareness of stakeholders.

The IWRM study found that IWRM is largely irrelevant to water supply in slums in developing countries. The reasons being it is too complex and there is uncertainty associated with the concept, providers often have minimal impact on the resource and little involvement with IWRM processes, IWRM reportedly doesn't work in informal economies and the donor popularity of IWRM has declined. However, the research found that IWRM can be relevant to providers when there is a localised water resource, water shortages are predicted, or the providers are involved in capacity building the regulators or representing disempowered users. To address the situations when IWRM is relevant a benchmarking process was developed to help encourage sustainability, participation, gender awareness and cost recovery.

1.5 Research Implications

The implications of the climate proofing work for water and sanitation services for the urban poor are: there maybe benefits associated with climate change (increased rainfall will have a positive impact on communities in drought prone areas); it is likely to be extreme weather which causes the most damage to communities and infrastructure; climate change may introduce unexpected risk to projects not designed for in current infrastructure in particular, increases in rainfall intensity; that for adaptation to be successful it needs to be integrated within existing plans and prioritising it alongside other risks; that the communities visited had minimal built-in resilience. The assessment of IWRM indicates that water and sanitation providers in slums should focus on what they understand as good water management and leave IWRM to higher level and policy organisations. The study did not assess how IWRM can be applied to adapt to climate change, despite its role being advocated in the literature. The principle reason is the concluded irrelevance of IWRM and the processes in which IWRM is advocated are generally higher level policy and institution change which have little application at the local scale. The evaluation of the strengths and weakness of the methodologies of the papers highlighted that work can be carried out by local organisation and that the work is simple to complete which should make it relatively easy to replicate. The conclusions of the work are supported by other studies at the local level and the implications from larger scale assessments; this bridging of regional policy at the local level is one of the main strengths of the work.

Paper I: Climate Proofing Water and Sanitation for the Urban Poor

The following paper reviews the climate methodology developed to assess the impact of climate change on WSUP projects and how they should adapt. It is based on the field work from Madagascar, Kenya and Zambia.

The paper is being prepared for the Journal of Environment and Urbanization

1 Abstract

Water is the sector most affected by climate change, as it's at the root of vulnerability, causing floods, droughts and less predictable weather. Climate change will affect the poor hardest, increasing migration to urban areas and impacting communities in slums. Despite an abundance of climate change resources, there are few specific to water and sanitation providers to the urban poor in developing countries. This paper presents a new methodology for water providers, which assesses how the predicted changes to climate will impact them and the existing vulnerabilities within communities; it then outlines how to climate proof their systems. The methodology was developed based upon field work with communities in Antananarivo (Madagascar), Naivasha (Kenya) and Lusaka (Zambia). The methodology consists of 5 steps: review the literature to quantify the changes to climate; undertake fieldwork to assess the existing vulnerabilities in the community using stakeholder interviews, focus groups and observation; produce hydrological scenarios based on the predicted changes to climate; assess the impacts of the scenarios and identify adaptations to climate proof the local service provider, utility and local municipality. This paper details the results of the application of the methodology to the 3 case studies and provides a review of the interviewed stakeholders' climate awareness. The results indicate there is a lack of climate awareness in developing countries, confirming that a simple approach to increase the robustness of water supply and sanitation systems is needed. For these case studies floods had a bigger impact than droughts and extreme events were more important than increases in temperature. The discussion synthesises the results from the case studies identifying common vulnerabilities and adaptations for flood and drought prone communities. This indicated that the adaptations required are nothing new, and could equally be described as 'good water management'. An evaluation of the methodology concluded it is an effective tool for converting regional climate predictions into local adaptations. The application of the tool highlighted that future climate proofing needs to focus on improving resilience, integrating adaptations within existing development, recognising the threat of new climate risks and that local capacity is limited in urban slums. The discussion reviews the implications of climate proofing highlighted that future climate proofing needs to focus on improving resilience, integrating adaptations within. The paper ends with an evaluation of the methodology concluding it is an effective tool for converting regional climate predictions into local adaptations and its main limitations are uncertainties clarifying the climate predictions and the impact on recharge/runoff.

Key Words: Adaptation, Developing Countries, Methodology, Resilience, Slums

2 Introduction

There are a wide range of uncertainties associated with predictions of anthropogenic climate change[1]. However, the scientific community widely accept that it is a reality[2] and even without anthropogenic change, climate variability undermines food security, negatively affects the environment and significantly affects livelihoods. Climate change not only refers to gradual change in mean climate, but also the degree of climate variability (affecting the frequency and magnitude of extreme weather) and can cause "modal" change in climate (climate shifts from relative stability to rapid change e.g. melting of a glacier). Water is one of the primary media through which climate change influences the Earth's ecosystems, impacting water supplies, river flows and groundwater[3]. Changes in rainfall patterns will increase, resulting in unfamiliar rainfall distributions; increasing the severity of floods and droughts[4,5]. Changes to rainfall will exacerbate current stresses on water resources (population growth and migration environmental degradation and land use change) making them difficult to manage, affecting the function and operation of existing water infrastructure, reducing food availability and impacting the livelihoods and well-being of societies[6].

Climate change will impact the poorest hardest, as the associated welfare losses are likely to be much greater for the poor in developing countries[7, 8, 9 ,10]. The majority of the poor live in ecologically fragile zones[11] and are heavily dependent on natural resources and sectors which are vulnerable to climate variability - for example a third of the African population live in drought prone areas[11]. Therefore, further changes to climate (particularly extremes) are likely to destroy livelihoods and deepen poverty – as even without climate change present climate volatility increases poverty levels[12]. The Stern Report[13] predicts by 2100, in South Asia and sub-Saharan Africa between 145–220 million additional people could fall below the $2-a-day poverty line, and every year an additional 165,000–250,000 children could die compared with a world without climate change.

The damage to livelihoods and resources caused by climate variability increases rural to urban migration - in sub-Saharan Africa rainfall shortages are correlated with increased urbanisation[14]. The majority of the urban poor live in deprived conditions with limited access to clean water or sanitation and are often on marginal land in flood-prone areas[13]. As a result, the urban poor are disproportionately threatened by the environmental hazards posed by climate change[9,12]. Water is typically sold to the urban poor through water kiosks and water vendors. The kiosks are either supplied by the main water utility or a local service provider (who may have a separate supply system or rely on the utilities). The providers are typically decentralised and have independent management, and are often supported and regulated through the city's main utility. The providers are better able to cope with the informal nature of peri-urban and informal areas but are often limited by lack of finance and technical capacity.

Climate change is severely impacting service providers supplying the urban poor. Current water management practices may not be robust enough to cope with the impacts[15]. All of the components of water supply systems are affected by direct impacts (physical changes to climate) and more uncertain indirect impacts (effects of climate change, e.g. migration or crop failures)[16]. In addition, hydrological design methods need to be evaluated as increased climate variability challenges the methods' main assumptions (a static climate)[5,17]. Presently African utilities' adaptations have been 'adhoc', only addressing short term concerns, and need to address climate vulnerability more systematically[18]. Many practitioners argue that it is not yet possible for water managers in developing countries to take climate change into account[5]. However, adapting to climate variability (increasing resilience, reducing vulnerability) is already an integral part of water management – the efficiency and success depends upon the utilities' governance[19].

"Literally hundreds of efforts are underway at many levels of government, and within departments of numerous international institutions devoted to preparing for adaptation to climate change"[20]- especially in the water resources sector[19]. Although few address water supply and sanitation for the urban poor, they do identify why a specific methodology is needed and the key aspects to consider in developing an approach. These are as follows:

- A thorough vulnerability analysis and impact assessment for enabling appropriate design and implementation of adaptation measures is lacking in almost all developing countries[21];
- There needs to be a shift from generic global impact assessments to more focused adaptation and response mechanisms[19];
- Community adaptation approaches have focused exclusively on agriculture[21;]
- Adaptations need to focus on increasing the resilience of water providers to climate variability[17];
- Adaptation policies work best when climate change initiatives link adaptation and development, addressing the structural condition causing social and urban vulnerability[22,23];
- Future long term changes can introduce new unexpected risks to projects[26].

The most relevant studies are the DFiD WHO Vision 2030[24] review and the CRiSTAL[25] and USAID Methodologies[26]. The Vision 2030 review comprehensively overviews the resilience of water and sanitation technologies, but lacks information on replication or assessing vulnerability. The other methodologies overview community vulnerability and adaptation but lack a water or sanitation focus. Therefore, a new methodology was developed specific to water and sanitation supply for the urban poor, in this paper. It was based upon the existing methodologies and field work in Antananarivo (Madagascar), Naivasha (Kenya) and Lusaka (Zambia). The methodology assesses how changes to climate interact with existing vulnerabilities in peri-urban and informal areas, and then assesses how to adapt the existing plans of water providers to increase their climate resilience.

3 Method

The methodology was developed in Zambia then trialled in Kenya and Madagascar. It consists of 5 stages: [1] A literature review, to identify the impacts of climate change; [2] Field work, to assess the existing vulnerabilities of communities and water providers; [3] Preparation of hydrological scenarios; [4] Assessment of the impact of the scenarios on the community; [5] Climate proofing of the project, to identify potential water and sanitation adaptations. A detailed literature review is provided in the climate proofing reports for each of the case studies (Appendix C, E, G) and a Terms of Reference (Appendix J) identifies the key stages.

3.1 Literature Review

A literature review was undertaken based mainly on the climate resources outlined in Table 1. The purpose was to identify the predicted changes to climate and the impacts upon water resources, health, livelihoods and biodiversity.

Table 1 Description of key resources for assessing impacts of climate change

Document	Description	Key sections
National Adaption Programme for Action (NAPA)[27]	Details the urgent and immediate needs and concerns of developing countries relating to adaptation to the adverse effects of climate change	Section 2: Framework for the Adaptation Programme; Appendix: review Proposed Adaptations to determine key vulnerabilities
National Communications to United Nations Convention on Climate Change (Non-Annex I)[28]	Details the results of national assessments of greenhouse gas emissions, as well as information on vulnerability, impacts, and adaptation. Observed and anticipated trends and impacts of climate change for each country can be drawn from these documents	Chapter 1: National Circumstances and Chapter 4: Vulnerability and Adaption Assessment
UNDP and Oxford University[29]	Country-level studies of climate observations and multi-model projections for 52 developing countries	General Climate; Recent Climate Trends GCM; Projections of Future Climate; Other Regional Climate Change Information; Data Summary

3.2 Fieldwork – Vulnerability Assessment

Semi-structured interviews, community focus groups and direct observation were undertaken over two weeks in each of the cities. Initially, interviews were arranged with the local service provider, water utility, meteorological organisation, local municipality and academics identified in the literature review. During the interviews, stakeholders were also asked to name other stakeholders that might provide useful insight. These included representatives from regional government, the scientific community and NGOs. The interviewees for the three case studies are detailed in Table 2 and stakeholder interview guides are listen in Appendix L.

Table 2 Number of interviews with each stakeholder for the 3 case studies

Stakeholder	Lusaka	Naivasha	Antananarivo
Community	10	10	2
Community focus groups	1	1	8
Local service providers	12	2	2
Utility	2	2	1
Council	3	2	2
Government	8	7	4
Researchers	2	1	-
NGOs	3	3	7
Consultants	-	-	2
Local business	-	2	2

The priority of the interviews was clarifying the causes and impacts of floods and droughts, the adaptations required and the plans of the water providers. The questions for the different stakeholders varied in the level of technical details and the topics covered, based on the stakeholders' role. The topics discussed were:

- **Climate change awareness:** assessment of interviewees understanding of climate change, its impacts and the current management adaptations;
- **Changes in climate:** review their understanding of the changes to climate predicted for the country;
- **Direct impacts of climate events** (floods, droughts, changes to seasons): discuss the impacts of the main climate events on the community, water and sanitation technologies and services;
- **Impacts of increasing temperature:** discuss the potential impact of changes to temperature;
- **Indirect impacts of climate change:** discuss how factors not directly related to water and sanitation are impacted and the effect on the community;
- **Water resources:** discuss the current situation, abstractions, discharges and management, review whether the current level of abstraction is sustainable;
- **Existing plans:** review the current procedures and future plans of the water providers;
- **Adaptations:** discuss how the community and local service provider adapt during current extreme events.

Community focus groups were completed with 8-16 people using a translator (the aim was for 8-10, but more attended). The focus groups consisted of a discussion of floods followed by a discussion of droughts. The focus groups began with a familiarisation exercise. Then the events prior to and during floods and droughts were discussed. This included questions on when the last event was, how often they occur, how much warning there is, their length and if there have been any noticeable changes in their frequency or nature. The impact of floods and droughts on the community was then discussed. This included the impacts on livelihoods, education, water supply, sanitation, health, buildings, women, consumable prices/availability and the community as a whole. The focus group were then asked to identify the largest problem. Following this, adaptation was discussed, debating the best way to adapt, reviewing who is responsible and the perceived role of local government, CBOs and NGOs.

Observation was used to verify the interviews and focus groups. This included general surveillance of hygiene practices, drainage and buildings, for example checking the quality of drainage channels, construction of latrines, hygiene standards and looking for water marks and other indicators of flooding.

3.3 Hydrology Scenarios Development

To assess how the predicted changes to rainfall and temperature impact the hydrology of the area, scenarios were prepared. As there was limited data, conceptual hydrological models of each city were developed. These were based on the field data and climate predictions for the region. For example, in Antananarivo there are high levels of runoff, which indicates the infiltration capacity has been reached, therefore future increases in intensity are likely to increase runoff. The model was then used to produce a number of scenarios, to account for the variation within the climate predictions. The scenarios were then used to predict the effect on any rivers, lakes, groundwater and specifically the effect on recharge and runoff levels. This analysis was used to assess if there was a risk from any of the following threats:

- Increased risk of flooding
- Increased groundwater recharge and a rise in groundwater level
- Increased runoff with more erosion
- Decreased water availability including less surface flow, drop in surface water levels and decreased groundwater levels

3.4 Impact Assessment

To assess the impact of climate change, the effect of the hydrological scenarios on the existing vulnerabilities, technologies and the existing plans was identified. Firstly, the effects of the scenarios on existing vulnerabilities were qualitatively reviewed. Then the impacts not directly related to water and sanitation, such as changes in food and electricity prices or employment, were assessed. Following this, the impact on the existing water and sanitation technologies was assessed, using Vision 2030[24,31]. resources. Vision 2030 details how water and sanitation technologies are vulnerable to the above threats. For example, for a borehole with an increased risk of flooding Vision 2030 identifies it may be vulnerable to increased contamination of groundwater from lateral flow in soil or inundation of the well. Vision 2030 then lists the impacts and possible adaptations. Finally, to assess how existing plans would be affected the plans were analysed to identify new risks, areas lacking resilience and aspects of the plan which could be vulnerable.

3.5 Climate Proofing

Once the impacts on the community, water and sanitation and existing plans had been assessed, adaptations were identified. Firstly, recommendations from the focus groups, interviews and the adaptations recommended for the technologies from Vision 2030[24] were assessed. Adaptations were included if they improved the systems' current resilience to climate variability, were appropriate to the service providers and addressed actual risks. Once the appropriate recommendations had been identified they were allocated to the local service provider, water utilities and municipalities dividing them based on timescale[30] and type of adaptation[31].

4 Results

This section summarises the results from the field work in Antananarivo, Naivasha and Lusaka. For more detail, comprehensive country reports can be downloaded (Appendix C, E, G)[32,33,34].

4.1 Lusaka – Zambia (Appendix C)

4.1.1 Background

Despite having abundant water resources (40% of the region's water[35]), Zambia experiences water scarcity. This is due to a combination of seasonal and temporal rainfall patterns and limited investment in infrastructure. The field work focused upon two peri-urban areas in Lusaka - Chazanga and Kanyama. Chazanga is north of the city centre, is hilly and has a population of 35,000 (2007)[36]. Kanyama is south east of the city and has a population of 198,000 (2007)[36]. Kanyama is very flat, rocky and is the natural drainage plain for the city; as a result it experiences severe flooding. Water is supplied to both areas by community organisations (Water Trusts), using boreholes and kiosks, which are supported by the city's main water utility.

4.1.2 Climate Change (Appendix B)

The main risks from climate change facing Zambia are an expected increase in floods and droughts combined with a reduction in *Miombo* woodland and maize yields. The mean temperature is predicted to increase with a greater frequency of 'Hot' days and nights and very few 'Cold'* days or nights. Total rainfall and rainfall intensity are expected to increase in summer and the frequency and intensity of extreme events, principally droughts and floods, is expected to increase[37].

4.1.3 Hydrology Scenarios

Two scenarios were developed for Lusaka, based around precipitation. Increasing precipitation is likely to increase the level of the main river (Kafue) and groundwater, increasing the intensity of localised flooding. Decreasing precipitation is likely to lower the groundwater level - the majority of interviewees believed abstractions were unsustainable. The impact of the decreasing rain on the river is uncertain but may reduce river levels. Basic Hydrology modelling was also undertaken for Naivasha detailed in Appendix E)

4.1.4 Vulnerabilities and Impacts

Chazanga is most vulnerable to a decrease in rainfall and a lower water table, increasing the likelihood of water scarcity, damage to infrastructure and drying up of shallow wells, all of

* Hot [Cold] days or Hot [Cold] nights are defined as the temperature for the hottest [coldest] 10% of days or nights (average).

which will increase the demand for new kiosks. Decreased rainfall could also affect hydroelectric generation, causing power shortages. However, if rainfall (or its intensity) increases, there is likely to be damage to boreholes, kiosks, septic tanks and pit latrines and the poor drainage at kiosks will be exacerbated. Lastly, there is likely to be an increase in climate-driven migrations to the area, increasing land pressure and exacerbating the problems associated with the limited latrine emptying options.

Kanyama is most vulnerable to an increase in rainfall, resulting in an increase in flooding (the last flood lasted for 3 months). Flooding causes kiosks and buildings to collapse, contaminates water supplies (particularly the shallow wells used in the areas unserved by the kiosks) and affects livelihoods, education and health. Flooded latrines and contaminated water increase the risk of cholera and diarrhoea. A decrease in rainfall would be beneficial for Kanyama, reducing the likelihood of flooding.

4.1.5 Climate Proofing

In Chazanga water shortages can be mitigated in the short term by acquiring a generator to mitigate power shortages; in the long term, the Water Trust Chazanga need to investigate alternative sources of water or deepen their boreholes. To protect infrastructure from heavy rainfall, the soil needs to be stabilised with buffer strips and erosion control measures and drainage standards for soakaways need to be improved.

In Kanyama, reducing localised flooding should be the priority. This entails working with the council and utility to develop the drains and clear them of rock and debris. The main health risks arise from latrines overflowing during floods. Possible adaptations are assistance emptying and raising latrines, and in the longer term installing decentralised sewerage; however, all the adaptations rely on improved drainage and the worst latrines are owned by the poor who can't afford to upgrade. To improve the health of the community the network needs to be expanded to ensure every household has access to safe water during floods. In addition, to support drainage the local water utility (Lusaka Water and Sewage Company) need to provide technical support and assist in mobilising finance, while the council need to establish better planning and zoning legislation.

4.2 Naivasha – Kenya (Appendix E)

4.2.1 Background

Profitable and expanding flower and vegetable farms (4000 ha exporting to Europe[38]) surround the lake, providing the basis of the economy. These led to a rapid growth in population. The farms abstract from the lake and employ cheap labour from the peri-urban areas and there is often conflict over declining water levels, increasing pollution and working conditions[38]. Three peri-urban communities were visited, Karagtia, Kamera and Mirera (population 54,000 (1999)[39]). Water is supplied via kiosks (sourced from groundwater) or collected/delivered (donkey vendors) directly from the lake. The communities suffer from droughts and flash floods which drain into the lake.

4.2.2 Climate Change (Appendix D)

Kenya is classified by the UN as a chronically water-scarce country (less than 2,74 m^3/person/day)[40]. Agriculture is the basis of the economy and is very vulnerable to increasing temperatures, droughts and floods. Mean temperature is predicted to increase with a greater frequency of 'Hot' days and nights and very few 'Cold' days or nights. Rainfall is anticipated to decrease in volume, increase in intensity and become increasingly irregular (observable in recent years). Extreme events will increase in frequency, intensity and spatial distribution (occurring in new locations)[41].

4.2.3 Hydrology Scenarios

Two scenarios were developed based around the mean lake levels. Decreasing lake levels and increased drought would occur if there were significant increases in evaporation and decreases in rainfall, offsetting any potential increase in rainfall intensity and runoff. Increasing (or static) lake levels would occur if there was increased rainfall intensity in the upper catchment leading to increased runoff and river flow, offsetting potential increases in lake evaporation and causing an increase in the number and intensity of flash floods.

4.2.4 Vulnerabilities and Impacts

Increased droughts and decreasing lake levels would result in increased domestic demand and a decrease in the availability of surface waters; however, the boreholes would be unaffected as the aquifer is confined. During droughts there are longer queues at kiosks, water vendors are more expensive and water takes longer to collect. The community cite the main issues as decreased income, ability to pay for water and increases in the cost of food. As a result, water use decreases, hygiene deteriorates and the prevalence of disease increases. In addition, when the lake's area decreases there is conflict over abstractions between pastoralists and farmers, employment reduces (as the commercial farms are not profitable) and the lake's quality deteriorates.

An increase in flash floods is likely to create problems for the community. Flash floods wash solid waste and silt into the lake, cause latrines to collapse and overflow, expose pipes, damages houses and crops and inundate roads which disrupt local businesses and schools. However, the community emphasise that flash floods are only an inconvenience, but health records display an observable increase in disease.

4.2.5 Climate Proofing

The water providers need to ensure affordable and accessible water, by maintaining low prices at the kiosks. The providers should support catchment management processes, ensure well heads are properly sealed and provide education about flood proof latrines (good seal, brick below ground level, compact soil and raise). The water utility (NAIVAWASS) need to incorporate the kiosks into their distribution network (as larger systems are more resistant) and adapt their system to better cope with flash floods, especially their sewage and treatment systems. The council need to maintain and develop drains, terraces and tree plant in the upper catchment and assist the regulator.

4.3 Antananarivo – Madagascar (Appendix G)

4.3.1 Background

The city of Antananarivo consists of a central urban district surrounded by peri-urban rice farms and hills. The central districts are not segregated by income; instead, large houses are surrounded by high density informal low-income houses. In Antananarivo 4 peri-urban and 4 informal communities were visited. The city is on the right bank of the River Ikapo and has protection from 1 in 100 year events while the peri-urban areas are on the left bank, only have protection from 1 in 10 year events. The city is drained by 3 main drains which are inadequately maintained and flood throughout the rainy season.

4.3.2 Climate Change[42] (Appendix F)

The mean temperature is predicted to increase; by 2055 the south of the country will be 2.6°C warmer and the north and coastal areas 1.1°C warmer. Medium rainfall and rainfall intensity will increase throughout the summer months, during the winter months the tropical regions will be wetter with more frequent storms while the south will be drier. The climate predictions in Antananarivo were unusual as the rainfall predictions are the opposite of the current rainfall trends. The frequency of cyclones is predicted to decrease in the early part of the main season and their intensity and destructive power are expected to increase towards the end of the century.

4.3.3 Hydrology Scenario

Only one hydrology scenario was used for Antananarivo - increasing rainfall volume and intensity. An increase in rainfall is likely to increase the volume of runoff and raise river levels, while increases in rainfall intensity are likely to cause more intense floods, which occur faster after rain. This will increase the risk of flooding from the river and the drains. Even if the frequency of flooding does not change, the increase in river levels will increase the number of days when the city drains can't empty and have to be pumped. Therefore it would take longer to clear the drains increasing the risk of flooding.

4.3.4 Vulnerabilities and Impacts

In the informal areas in the city the frequency and severity of flooding from the drains is likely to increase. Flooding is a major health risk and disrupts the lives of communities. Water gets into houses, employment decreases, travel is difficult and the environment becomes dirty, odorous and very unpleasant. Household latrines overflow, their superstructures and pits collapse, flying toilets increases (defecation in plastic bags), there are long queues at kiosks, taps can be submerged and the water pressure is lower. The water supply infrastructure installed by NGOs is resilient to flooding, but the water supplied by the utility (JIRAMA) is contaminated during floods as the catchment isn't protected, there is high non-revenue water and the water has a high sediment content (increased run-off increases soil erosion).

The upland peri-urban areas may experience increased surface runoff while the lowlands and paddies could flood from the drains or river. The impacts would be similar to the informal areas, with the addition of damage to crops and livestock and greater livelihood vulnerability. However, in the peri-urban areas there is typically more space to implement local coping mechanisms.

4.3.5 Climate Proofing

There is already an awareness of the importance of addressing the poor sewage and storm water management in Antananarivo and strategy has been developed. Therefore the priority should be supporting this existing plan, emphasising that flooding will be more significant and requires more resources. Adaptations were also identified for 40 areas modelled[43] as especially vulnerable to flooding. In these areas water providers should monitor water quality, chlorinate and provide education on latrine and flood adaptations. The water utility (JIRAMA) should undertake a programme of leak detection, pipe maintenance and reduce illegal connections to minimise contamination of the water supply and improve the hydrostatic pressure. Their treatment system also requires additional treatment to cope with the high sediment loads during floods. The Communes need to focus on clearing the drains, and assisting the other drainage organisations and they should improve waste and sanitation to reduce dumping in drains. It is also important they minimise the occupation of areas not designed for habitation on the city plan.

4.4 Climate Change Awareness

During the interviews the overall awareness to change was qualitatively reviewed and the results for the different stakeholders are summarised in Table 3. The table indicates that local institutions, water utilities and communities in the three cities were unaware of climate change and have few plans to adapt. In government there is generally some awareness at the policy level, but little impact on the ground.

Table 3 Stakeholders awareness of climate change and their plans to adapt

Stakeholder	Awareness	Plans/Actions	No. Interviews
Community	Limited	None	30
Local service providers	Limited-Medium	No direct plans	26
Utility	Limited-Medium	No plans - aware need to adapt system but no direct plans	5
Council	Medium	No direct plans – Lusaka council has climate change department	7
Government	Awareness at policy level but little implementation	- Involved in UNFCCC dialogue - Some form of climate change department/networking organisation - REDD process (deforestation) - Little regional or district work being completed, seen as issue for central government	19
Researchers	High	Studies being undertaken and advocacy work	3
NGOs	Most have high awareness, but some are limited	- No direct plans - Impact and vulnerability assessments - Set up partnerships/advocacy forums	14
Consultants	Medium	No current projects	2
Local business	High	Aware of need to incorporate the impacts	2

5 Discussion

The results detailed the predicted changes to climate for each city and the likely impact on the hydrology. They reviewed the impact of these changes on the existing problems, water supply and sanitation and detailed the potential adaptations required to increase resilience. The results highlight that the predicted changes to climate and resultant impacts on hydrology are likely to have significant effects upon existing vulnerabilities.

5.1 Commonalities between Case Studies

In the case studies, floods had a bigger impact than droughts. Of the 11 communities visited during the field work, 8 were vulnerable to flooding and 4 to water shortages. In the communities some of the impacts were similar and are divided between regional and local scales in Table 4. Regional impacts are generally more significant, as they affect more people, cause more damage and often rely on governments' and institutions' interventions. For example, during a regional drought everyone is impacted by food shortages, reducing available incomes. The main differences between the cities arose from the possible indirect impacts of climate change, which would stress existing systems. For example, in Kenya, droughts affect food prices, hydroelectric production and increase the demand for water, combined with reduced employment and an increase in the cost of consumables, especially charcoal and staple food crops (e.g. maize or rice).

Table 4 Impacts on the low-income urban areas

	Flooding	**Droughts**
Local	**Localised (if drainage capacity is inadequate):** - Pipes exposed - Taps submerged - Siltation of water resources - Contamination of boreholes - Latrines overflow - Latrines/buildings collapse - Solid waste dispersed - Water in houses - Roads damaged/impassable increasing the cost of charcoal and food - Disease increases especially malaria, dysentery and diarrhoea - Employment decreases - Income generating activity decreased	- Water shortages - Water cost increases - Less water for health and hygiene - Long queues at kiosks/boreholes - Water pressure drops - Livestock suffer - Crops destroyed - Increased poverty - Education suffers (less money for school fees) - Malnutrition - Health issues
Regional	**River (if riverine flood defences are breached):** - Infrastructure damaged - Increased treatment costs - All the above factors plus: - Crops damaged - Road network damaged - Drowning	- Water bodies dry up - Increased abstraction conflicts - Food insecurity – food costs increase - Hydroelectric shortages

The adaptations to the vulnerabilities were specific to each city; however, there were common adaptations to droughts and floods for local service providers, utilities and municipalities. The common adaptations are detailed in Table 5 and are a mixture of infrastructure and monitoring programmes and education and mobilisation aspects. They demonstrate that adapting to climate change does not typically involve many new processes - the adaptations could equally be described as good practice in flood or drought prone areas.

The research aimed to undertake comparative analysis of the three case studies to draw inferences about the types of management which make for effective/ineffective management/delivery or identify situations which provide the best conditions for mainstreaming adaptation concerns, but this was no possible. Principally due to time constraints, as completing the 3 case studies required the majority of the resources. But also as completing the task would require the management and core aspects to benchmarked to allow comparative analysis requiring detail contextual analysis before identify common themes and judging what is effective at this stage is difficult as the adaptations are only recommendations. To complete the analysis the climate proofing reports need to be reviewed (Appendix C, E, G) and the recommendations which are eventually implemented needs to be assess with further visits to see how the areas cope with future events.

Table 5 Common adaptations for areas at risk to flooding or drought

	Risk of Water Shortages (droughts)	**Risk of Floods**
Local Service Provider	- Ensure affordable and accessible water supply - Expand kiosk network into unserved areas - Investigate alternative supplies to use during droughts - Community education and hygiene promotion on the risks to health during droughts	- Community education and hygiene promotion on the risks associated with floods - Education on best practice for latrine construction to avoid latrines collapsing or overflowing - Protect boreholes and pipe network from flooding - Regular sanitary inspections during floods - Tighter enforcement against fly tipping - Chlorinate water supply during floods
Utility	- Support the expansion of new kiosks - Build new storage tanks - Investigate the recharge rate/sustainable yield of aquifers	- Leak detection and pipe maintenance - Reduce illegal connections and improve the hydrostatic pressure - Monitoring water quality during floods - Regular inspection of infrastructure during floods
Municipality	- Engage in water allocation dialogues	- Improve drainage systems: clear and maintain drains, legislation against dumping - Improve solid waste collection - Subsidise tanker/waste disposal options - Land management activities to reduce severity of floods

5.2 Implications of Findings

Figure 1 synthesises how changes in rainfall (the most significant factor in the scenarios) impact flood and drought prone areas. This illustrates that there maybe benefits associated with climate change, for example, increased rainfall will have a positive impact on communities in drought prone areas. However, in most cases the negative aspects will be more significant and even for drier futures, if the frequency and intensity of extreme storms rises, flooding patterns may not change significantly.

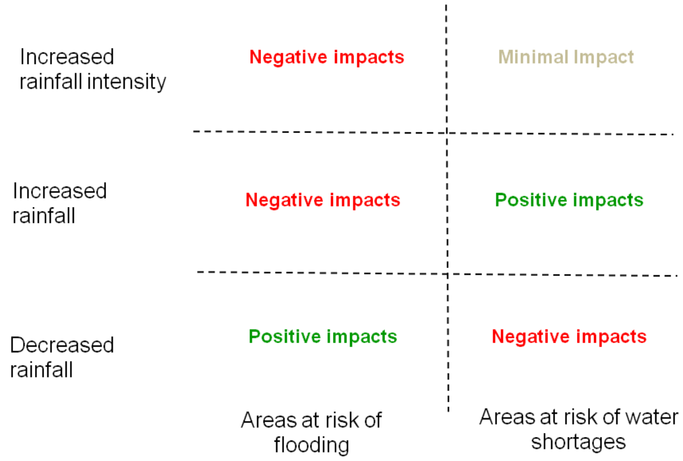

Figure 1 Impacts of climate change on flood and drought prone areas

The results predict that although temperature rises will have a significant effect on water resources, it is likely to be extreme weather which causes the most damage to communities and infrastructure. This conclusion is shared with the CAPNET (2003)[44] climate change adaptation guide, which emphasises building capacity to deal with unpredictable events, managing risk and prioritising no-regret measures. An increased frequency of extreme events will affect weather patterns and averages, which may have a significant effect as the changes may introduce "unexpected risk to projects"[26] not designed for in current infrastructure. In particular, increases in rainfall intensity are likely to affect flooding and drainage, for example there may be a higher risk of borehole contamination after heavy rainfall. Therefore, local examples from regions with experience of the more extreme climates will be increasingly helpful to organisations planning adaptations, as they can provide details of potential risks and design features.

The results appear to support the findings of Sanchez-Rodriguez (2009) and Simon (2010), that for adaptation to be successful it needs to be integrated within existing plans and prioritising it alongside other risks. For example, the Sanitation Master Plan in Antananarivo provides a comprehensive overview of how to adapt to flooding and the roles of the different stakeholders, based on detailed research. If adaptations were developed independently they are unlikely to capture the more nuanced details of a locally prepared plan, and may compete for funding or introduce confusion. Allen *et al.* (2009) found that the poor have a certain level of built-in resilience (preventative and impact minimising economic strategies, asset accumulations, and social support networks) which must be recognised and better supported by planning initiatives[45]. However, for the communities visited there was minimal built-in resilience, due to limited assets, education and resources. This is either a result of the communities being poorer or as less time was spent with the communities, built-in resilience may not have been captured by the fieldwork.

The limited climate awareness of stakeholders reinforces the need for a simple method for climate proofing. This is supported by the findings of Satterthwaite *et al.* (2007), that local government fail to efficiently address the impacts of climate change[46]; Sanchez-Rodriguez (2009), that a thorough vulnerability analysis and impact assessment for enabling appropriate design and implementation of adaptation measures is lacking in almost all under developing countries and Muller (2007), that few countries have begun to review their design standards from a climate change perspective. This reinforces the need for an appropriate method to assess the impacts of climate change at both the vulnerability and modelling level, to identify pragmatic and rigorous adaptations to climate change. This is especially important as the infrastructure built today locks us into patterns of behaviour for many years to come[17].

5.3 Evaluation of Methodology

Essentially, the methodology identifies the adaptations that local service providers could implement to increase their climate resilience, as well as identifying the adaptations required by the utility and municipality to support them. Its main strengths are that it applies regional climate modelling to local vulnerabilities, it is based on multiple scenarios describing the impacts of possible futures, and it was developed and trialled based on field work, ensuring it is workable and relevant. The methodology draws heavily upon the Vision 2030 overview of the vulnerabilities of water and sanitation technology and potential adaptations[31], but integrates them within the context of the existing vulnerabilities. The method incorporates the community approach used in CRiSTAL[25] and the assessment of existing climate vulnerabilities used by USAID[26] with the addition of an assessment of the impact of climate change on the hydrology. Lastly, although the methodology is designed for smaller operators, the approach can be applied to larger suppliers, if more detailed hydrological modelling is undertaken. Nevertheless, the methodology does have limitations and these are outlined for each stage below.

5.3.1 Limitations

The uncertainties associated with climate modelling, physics and scenarios make it difficult to quantify the climate changes for a country. Changes to temperature are more certain (globally increasing) than changes to rainfall, especially with regards to simulating tropical precipitation, due to uncertainties with positioning the Intertropical Convergence Zone[47]. Climate predictions are given as probabilities or with wide ranges making it difficult to quantify actual changes. The uncertainty is even greater at the city scale as there has been little downscaling of the models and the predictions are based on interpolations. The exception was Madagascar where there had been detailed modelling and analysis of the region[42].

In Lusaka, community data was collected using interviews; these often failed to yield sufficient depth and individuals cited similar impacts. Therefore, more focus groups were used in Naivasha and Antananarivo, as they identified a broader range of impacts, and groups often verified their answers through the discussions. It was also difficult to explore the impacts of possible new risks as the community hadn't directly experienced the effects. The interviews with more educated individuals including community leaders were more insightful, requiring less probing to highlight secondary issues. The main limitation was that more revenant concepts emerged as interviews progressed, so that discussion of these was missed with early informants. This was particularly a problem in Antananarivo which is substantially larger and it was not possible to visit all of the communities, whereas in Lusaka and Naivasha all of the communities were visited. To address this, some of the first stakeholders were interviewed at the end of the fieldwork. Likewise, the smaller populations meant Lusaka and Naivasha had more representative samples.

Converting the climate predictions into local impacts is the most uncertain aspect of the methodology, largely due to the lack of, and low quality of, hydrological and climate data. A conceptual hydrological model based on hydrological principles was developed and used to define scenarios for the various climate projections, as this requires less data. However, uncertainty remains in estimating the effect on infiltration capacity (affecting recharge and runoff), due to the interrelated nature of hydrological processes, especially when rainfall volume is predicted to decrease while its intensity increases. This is significant as small changes in rainfall are often amplified in the responses of water resources, leading to large changes in stream flow[17]. However, as the scenarios focus upon the impact of extremes and the potential impacts on the main hydrological features, not specific events, lower levels of accuracy can be tolerated.

The assessments of the impacts of the scenarios were relatively easy to interpret and provided a clear insight into the risks; however, sometimes the intensity of the impacts (and resultant effects) was difficult to clarify. Likewise, most of the climate proofing effectively identified adaptations, but for some there was insufficient knowledge of the system design, layout and soil structure or insufficient information on existing plans to provide detailed specifications. However, this can be addressed by focusing on these aspects during field work. The main external limitations were that the water and sanitation services to be climate proofed are in urban slums where there are lower income levels, deficient basic services and tariffs are not cost reflective. Therefore adaptations will often be secondary to providing basic supplies, for example installing a pump to supply the kiosks in one of the communities of Naivasha, but nonetheless they are central to projects' sustainability.

6 Conclusion

The general lack of climate change awareness in developing countries means it is essential to have a simple method to climate proof water and sanitation services for the urban poor in developing countries. Some of the main risks to water and sanitation providers are from changes to the frequency and intensity of extreme events, especially an increase in floods or droughts. The methodology developed converts regional climate predictions into local adaptations, providing a tool for climate proofing urban supplies. In addition, by dividing adaptations between the stakeholders the process raises awareness at different and levels.

The recommendations identified by the methodology highlight that adapting to climate change often does not involve many entirely new processes or techniques; instead it requires a combination of capacity building, technological and managerial measures. Water providers should not consider climate change in isolation, but rank and prioritise it against other sources of change, risk and uncertainty. They need to focus on increasing the environmental resilience and disaster preparedness of projects and the robustness of existing systems. It should, however, be made clear that this is not an argument for 'business as usual' and climate change adaptations should not simply be 'bolted on' to existing plans. Instead, changes need to be properly assessed, as future long term changes can introduce new unexpected risks to projects. In particular, risks arising from increases in rainfall intensity should be considered, as although current intensities may not cause problems, increases will change runoff and potentially cause localised flooding.

Lastly, climate proofing is less urgent when adaptations have been identified to address existing environmental issues (for example, flooding in Antananarivo); however, climate proofing will still be applicable and necessary to identify potential new risks and priorities for action. In particular, when rainfall trends reverse or there are dramatic changes predicted (e.g. rainfall that is currently increasing is predicted to decrease), the affects of climate change should be reviewed anew.

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Paper II: The Relevance of Integrated Water Resource Management to Water Providers in Urban Slums in Developing Countries: Examples from Zambia

The following paper assesses the relevance of integrated water resource management to water and sanitation providers in peri-urban and informal areas in developing countries. It is based upon the field work in Zambia.

The journal for this paper is still under discussion

1 Abstract

Integrated Water Resource Management (IWRM) is widely advocated for ensuring collaborative and equitable use of water resources. Despite this, it is unclear what IWRM really means and for small water providers there is confusion regarding whether, or how, they should be implementing it. This paper assesses the relevance of IWRM for water and sanitation providers to slums in developing countries, and how it can be applied, through a literature review and field work in Lusaka, Zambia. The review summarises definitions of IWRM, how it is applied, its relevance to water and sanitation, urban areas and developing countries and the main criticisms of the approach. The review highlights that IWRM is relevant to water and sanitation at abstractions and discharges, that urban areas have been neglected and that IWRM has been widely applied in developing countries, but to limited effect. IWRM principles were converted into a benchmarking process consisting of a series of questions and indicators, discussed in semi-structured interviews and analysed using a Strengths, Weaknesses, Opportunities and Threats framework to clarify 2 water providers' sustainability in Lusaka, (Chazanga and Kanyama Water Trusts). The process provided insight into the Water Trust's application of IWRM principles, indicating high levels of community ownership and gender representation, but little understanding of resource sustainability and limited cost recovery. The study found that IWRM is largely irrelevant to water supply in slums in developing countries, as IWRM has no operational definition; water providers do not interact at the scales for which IWRM is intended; it doesn't work in informal economies; it is too complex; and donor favour for IWRM processes has declined. However, the principles of IWRM are relevant when there is a localised water resource, water shortages are predicted or the providers represent disempowered users. In these situations, the benchmarking process provides a method to ensure the principles are applied; alternatively, Water Safety Plans can be applied as they are specific to water suppliers.

Key words: Benchmarking, Community, Critique, Review, Sustainability

2 Introduction

Integrated water resource management (IWRM) was advocated by donors and policy makers during the 1990s, who emphasised the importance of the sustainable management of resources and collaboration between different stakeholders[1], although in recent years the popularity of IWRM has declined and its relevance has been questioned by academics and practitioners[2]. There has been little work assessing the relevance of IWRM to the provision of water and sanitation in slums in developing countries. The term slum here refers to informal, peri-urban and low income areas. Existing studies on sanitation concentrate on elements of the sanitation chain or fail to address "how sanitation fits within the IWRM framework and development in Africa" Mazvimav *et al.*, (2010)[3]. This paper aims to address this gap using a literature review and by developing a benchmarking process to review how organisations currently implement IWRM.

2.1 IWRM Background

IWRM emerged in 1992 as an accepted alternative to the previous sector-by-sector, top-down water management approaches[4]. The Global Water Partnership (GWP) (the self appointed guardian of the concept[5]) defines IWRM as a process which "promotes the coordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital eco-systems[6]". There are various other definitions, but all contain the principles of equity (in terms of access to water resources and benefits), efficiency and environmental sustainability[5]. It grew out of a recognition that different users of water resources are interdependent and unregulated use of scarce water resources is wasteful and inherently unsustainable[1].The philosophy of IWRM was accepted by the governments of the world as the recommended paradigm for water resource management at the 1992 UN Earth Summit[7] and the core principles (Box 1) were agreed at the International Conference on Water and the Environment in Dublin in 1992[8]. Its popularity was driven by the recognition that water resources were degrading and the poor management and governance of water. To many, IWRM is nothing more than the process of implementing the principles[5].

- Principle 1: Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment
- Principle 2: Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels
- Principle 3: Women play a central part in the provision, management and safeguarding of water
- Principle 4: Water has an economic value in all its competing uses and should be recognised as an economic and social good

Box 1 Dublin Principles 1992

2.2 Implementing IWRM

IWRM calls for a broader systemic approach to water management, to encourage the coordinated use of land, surface water and groundwater by upstream and riparian users. The GWP provide guidance on the 'Why, What and How' of IWRM and believe successful implementation relies on a combination of an enabling environment, reformed institutional roles and established management instruments[6]. IWRM is described as an iterative, ongoing process, affecting water allocations, pollution controls, monitoring, finance, basin planning and stakeholder engagement. At the national level, IWRM entails legislative, legal and institutional reforms to encourage cross-sector activities at the catchment scale. At the project level (also known as 'local water management' or 'light IWRM[9]) implementing IWRM focuses upon the application of the Dublin principles within sub-sectors (mainly agriculture, industry, water supply and the environment) The logic is that if all subsectors apply good local IWRM this will lead to better water resource management and encourage wider implementation of IWRM[9]. However, local IWRM is unable to resolve conflicts and assign allocations if the over-arching legal and institutional framework is missing or ineffective[5].

Various projects have applied local IWRM (EMPOWERS[10], LoGo Water[11], SWELL[12],WATERCOURSE[13], WHIRL[14]). The projects focus upon community participation. The methods vary but the main components are working with community knowledge and existing institutions, identifying risks, capacity building, active learning, engaging with local stakeholders and empowering them to make decisions. The projects are based on a belief that fostering community ownership and local decision making improves project sustainability. Additionally, the hope is that success at the local level encourages buy-in from larger organisations, increasing the influence of the project and IWRM processes. The local focus also makes the approaches better able to adapt and incorporate informal structures and institutions. Alongside this there has been a renewed drive for infrastructure projects to compensate for the perceived ephemeral nature of IWRM[15].

2.3 Relevance of IWRM

2.3.1 Water Providers

The water and sanitation sector interacts with other users and the environment through abstractions and discharges. These affect pollution, competition and water resource sustainability. IWRM approaches are relevant when there is a failure to consider downstream users; when administrative and riparian boundaries vary; and demand is similar to supply.[5] In the latter, conflicts can arise as domestic supply is given national priority and its demand is considered trivial but during the dry seasons or droughts it can represent a significant share of resources. In these situations IWRM is especially relevant for water providers as normal mechanisms to prioritise domestic water use often fail due to increasing resource competition[5]. IWRM also provides a framework for managing increasing pollution and ensuring good practice within smaller decentralised systems. "Yet to date the water and sanitation community has failed to engage adequately with IWRM" (IRC, 2004).

2.3.2 Urban areas

There has been little application of IWRM in urban areas, as they have erroneously been considered as separate from river basin management[16]. Yet cities are dominant features within catchments, impacting rural water supplies, down-stream users, and agriculture[17]. At the city scale, IWRM is relevant for addressing the complex sets of interdependent relationships existing within and between human and environmental systems. It provides a framework for addressing issues of water utility, demand, affordability, recreation, and stakeholder satisfaction[18]. Furthermore, urban areas have more stakeholders than rural areas that are often fragmented in their roles and responsibilities. Coordination can be a significant challenge in urban areas and traditional implementation is often inappropriate as access and use of information is often limited. This reduces the effectiveness of IWRM processes.

2.3.3 Developing Countries

IWRM is advocated as a means to advance progress on the Millennium Development Goals (1,4,5,6 &7)[19], as it encourages the sound management of freshwater resources, supply of unpolluted water and environmental sanitation. Developing countries have been actively encouraged to shift from supply augmentation to demand management under the broad framework of IWRM[5,20]. However, the actions implemented often take a narrow view of IWRM, applying a generic package[20]. For example "drafting new water laws is easy; enforcing them is not. Renaming regional water departments as basin organisations is easy; but managing water resources at basin level is not. Declaring water an economic good is simple; but using price mechanisms to direct water to high-value uses is proving complex" (*Ibid.).*Consequently, IWRM initiatives in developing contexts have proved to be ineffective at best and counterproductive at worst[7,20]. This is often exacerbated by a lack of political will to seriously engage in changes to water policy, limited finance, low awareness of water issues, weak human and institutional capacity, and discontinued support programmes[16]. In addition, developing countries have large informal water sectors, which depend upon self-provision, informal exchanges and local community institutions not under the direct influence of formal public institutions. Therefore the traditional institutional and legal reforms IWRM applies are often inappropriate[21].

The 2008 Capetown IWRM conference[22] reviewed the implementation of IWRM in developing countries. In a synthesis of the conference Anderson *et al.,* (2008)[4] stated there was general agreement with the principles, but an agreed need for greater community focus and engagement, integration of long-term resource planning, work with city stakeholders and more appropriate economic instruments and targets[4]. Colvin *et al.,* (2008)[13] presented results from a joint project in South Africa (one of the first countries to apply IWRM nationally) that focused on moving towards decentralisation, capacity building and interactive learning. Stressing that "IWRM is no longer a thing to do but an interactive and emergent process of adaptive water resource management"[13].

2.4 Criticisms of IWRM

There is a shared faith in the aims of IWRM, and the philosophy is hard to disagree with, but "despite some achievements and extraordinary capital investment, national governments have by and large failed to sustain truly integrated programmes"[23]. IWRM is strongly criticised for failing to translate theory into action[24,25]. Biswas (2008) one of the strongest critics of IWRM, "argues there is absolutely no evidence from anywhere in the world that it will work for macro- or meso-scale policies, programmes and projects on a long-term basis".

A recurring criticism is that IWRM lacks a clear operational definition and as such the implementation depends on the individuals involved. This is exemplified by interviews with IWRM practitioners of substantial experience who were unable to comprehensively define and describe the concepts and their purposes[2]. Often the changes made are superficial and have little effect on the way water is used and managed on the ground. However, these failures are largely a result of the complex nature of the concept rather than failings of the practitioners - IWRM attempts to simultaneously address two highly complicated goals: sustainable development and cross sector planning[26]. Various reviews have evaluated IWRM success and the main criticisms are synthesised in Table 1. In response the latest GWP (2010) review[27] describes IWRM not as a prescription but a practical framework for addressing water management challenges, stating that it is not an end in itself. More specifically they highlight the importance of higher level support (policy and institutions), that applications will be specific to each society, that there is not necessarily a contradiction between protection of the environment and economic growth and that there is no 'magic bullet' for water management.

Table 1: Meta Analysis of Criticisms of IWRM, X indicates criticism discussed in the paper

Criticism	Papers				
	Du Toit[28]	Biswias[29,30]	Jeffrey[24,26]	Glass[25]	Cardwell[31,]
No evidence of successful application		X	X		
Complexity of approach and feasibility of implementation		X	X	X	X
Ambiguity of definition means it covers too much		X	X		
Usefulness of generic approach for individual projects		X		X	
Inappropriate for existing institutions with defined roles			X	X	
The lack of agreed indicators, makes it difficult to compare and evaluate projects		X			X
Meaningful participation and engagement are missing	X			X	

3 Method

Local application of IWRM is concurrent with the scale of water supply in slums, yet it is unclear how IWRM should be applied by small scale water providers. To assess the relevance of IWRM a benchmarking process was developed based upon the Dublin principles. The process aimed to benchmark the current application of IWRM by organisations, what they use it for and its benefits. The process consisted of a series of questions based around the principles of IWRM, divided between aspects within and outside (external to) the supplier's control (Table 2). For each question more detailed indicators were used to explore specific aspects. The questions focused upon small water and sanitation suppliers to avoid the more complex and ambiguous processes associated with implementing IWRM processes at larger scales. In addition, to clarify the role of IWRM the process aimed to emphasize sustainable water resource management, highlighting the importance of gender, participation and water resources.

Table 2: Final Version of benchmarking questions and key indicators. External factors are those outside the service provider's control

Question	Indicators
Principle 1 Resource Sustainability	
Does the local service provider understand the water resource?	Knowledge of catchment, abstractions, sustainable yield, recharge rate
How is the water resource impacted by the service provider?	Pollution of the resource and water quality
How does the service provider protect their abstractions?	Enforcement, legislation, catchment safety measures
Is there any abstraction conflict between users?	Number of users, volume abstracted, seasonal variations, past conflicts, resolution mechanism
Is the area affected by floods?	Impacts, robustness, adaptation, length, severity
Is the area affected by droughts?	Impacts, robustness, adaptation, length, severity
Is water supplied 24 hours a day in the dry season (droughts)	Number of hours water is supplied, kiosk's reliability
Is water supplied 24 hours a day during floods?	Number of hours water is supplied, kiosk's reliability
Is water used efficiently by the service provider?	Waste water, nonrevenue water, level of meterage
External	
Are the total abstractions from the water resource sustainable?	Water level fluctuations, supply vs. demand, environmental reserves
How is the water resource impacted by the community and other stakeholders?	Pollution levels
How is the environment protected?	Legislation and implementation
Principle 2: Participation & Collaboration	
Is there community ownership of infrastructure provided by the local service provider?	Level of vandalism and community commitment
Are the community consulted on new projects?	Community participation and engagement
How are complaints from the community to the service provider recognised?	Feedback mechanisms and responses
What proportion of the service provider's budget is spent on capacity building in the community?	Level of hygiene promotion
What is the community's perception of the service provider?	Perception of corruption, efficiency and equitability
What is the government/utilities/NGO perception of the	Perception of corruption, efficiency, replicability

service provider?	and equitability
External	
Is there community understanding of the water resource?	Perception of risks
Is there utility/Government understanding of resource?	Awareness of risk and sustainability
Principle 3: Gender	
What is the service provider's awareness of the importance of gender?	Awareness of gender differences
Are women's roles and needs in water identified by the service provider?	Involvement and need representation
Do women have equal opportunities within the service provider?	Opportunities
External	
What are the differences between men and women in participation in and influence over general decision making in the community?	Women's influence and power
Are women involved on water committees?	Level of representation
Principle 4: Cost	
What is the level of cost recovery operated by the service provider?	Income, maintenance costs
Does the service provider have enough money for repairs?	Current maintenance requirements, ability to deal with major repairs
Does the service provider have sufficient technical capacity?	Level of training and qualifications of staff
Is the cost of water fair?	Affordability and willingness to pay
External	
Is the price of water subsidised?	Level of subsides and financial sustainability
Who pays for pollution?	Polluter pays, enforcement and regulation

The benchmarking process was developed and tested by applying it to Lusaka in two peri-urban areas - Chazanga and Kanyama. Chazanga is north of the city centre and has a population of 35,000[32], it is hilly and water is supplied by a community organisation (Water Trust) using boreholes and kiosks. Kanyama is in the south east of the city and has a population of 96,00[32]. Kanyama is very flat, rocky and is the natural drainage plain for the city; as a result it experiences severe flooding. Water is supplied by a similar community organisation to Chazanga. Both of the Water Trusts operate private boreholes but receive technical support from Lusaka's main water utility - Lusaka Water and Sewage Company (LWSC). The Water Trusts work with LWSC to apply for centralised funding from Zambia's regulator (NWASCO).

Semi-structured interviews were conducted with members of the community, the service provider (Water Trust), the utility that supported the Water Trusts and relevant Council, Government, NGOs and research institutions using a draft version of the questions in Table 2. The number of interviewees with the different stakeholders is listed in Table 3. Community participants, were selected through convenience sampling based on three transects, starting at the Water Trust's compounds, interviewing individuals available en route. An interview was scheduled with the managing director of each Water Trust; other staff available during the visits were also interviewed. Community interviews were completed with a translator and all interviews were recorded. As Interviews were completed during the day, the majority of working (and more educated) individuals were at work; however, as the peri-urban areas are not secure after dark, there was no alternative. Interviews with the other stakeholders were based on the community interview guide but covered more technical aspects and also included a discussion of water supply, finance and the main risks to the system. All of the interviews lasted between 30 and 90 minutes. The final benchmarking questions were refined after the field work based on the experience.

Table 3: Stakeholder Interviewees

Stakeholder	Community	Water Trust	Utility	City Council	Government	Research	NGOs	Total
No. Interviews	11	12	2	3	8	2	3	41

The responses to the questions were analysed using a Strengths, Weaknesses, Opportunities and Threats (SWOT) framework. For each question the responses were synthesised extracting the common themes and these were entered into the SWOT. The themes were listed as positive, negative or neutral; positive themes which the service provider had some control over were then placed within Strengths, while negative themes were placed within Weaknesses. External themes were placed within Opportunities and Threats. The SWOT analysis provided a snapshot of the Water Trust's sustainability and was used to assess the relevance of IWRM to each Water Trust. Firstly the strengths gave insight into the aspects of IWRM which are already practiced by the Water Trusts, while the Weaknesses identified areas were the principles of IWRM are not practised. The themes within Opportunities and Threats indicated potential vulnerabilities and partnerships for the Water Trusts.

4 Results

The result of the SWOT analysis for Chazanga and Kanyama were very similar and are presented together in Table 4. The Water Trusts main strengths are their community roots. As the Water Trusts were founded by the community there are high levels of ownership, participation and engagement. Both Water Trusts require committees to be at least 50% women and employ mostly female vendors. Communities were engaged in deciding the price of the water and respondents believe the price is affordable and necessary (once the principles of cost recovery were explained). At the technical level the Water Trusts protect their boreholes from contamination by creating buffer zones, metering all kiosks and connections and they are able to fix most routine issues. The weaknesses of the Water Trusts relate to their technical and financial capacity. The Water Trusts lack technical specialists, and are unable to address technical issues with equipment (although they are supported by LWSC so this is less of a concern) and there have been no attempts to quantify the resource's sustainability (less of a priority in Kanyama as the water table is at 2m). The lack of finance limits the expansion of the kiosk network to areas unserved and any large scale investments require external support.

Table 4: SWOT analysis of Environmental sustainability audit of Chazanga and Kanyama Water Trusts (WT = Water Trust)

	Positives	Negatives
Internal Factors	**Strengths** • Majority of households can afford water for all domestic uses and think the price is fair • Women have equal job opportunities within the WT • WT design program to specifically address gender differences • The WT run quarterly hygiene promotion and training of vendors • Individuals and the committee can report on problems with system and there is always a response • Community decides location of kiosks • Strong ownership and minimal vandalism (community invest time and resources in infrastructure) • Non revenue water less than 5%; minimal wastage, meters on most kiosks and homes • WT own the land surrounding abstraction, enforced minimum distance from latrines/rubbish • Reportedly no pollution from WT little deterioration of water quality in last 5-10 years	**Weakness** • WT able to fix routine problems, but unable to deal with technical problems due to lack of training and cash • WT have limited understanding of water resources, but are aware of other abstractions • Water costs are increased to subsidise sewage, initial investment required from donors • Limited funds to expand network into unserved areas • WT have limited understanding of risks to water resource

	Opportunities	Threats
External Factors	• Women have equal influence and power • High gender awareness in community • New borehole act should increase sustainability of supply	• Groundwater abstraction not sustainable • Contamination of groundwater from onsite sanitation and septic tanks • Mines have stopped pumping water back into Kafue river, reduction in low flows • Climate change[33] • Reliance on external donor funding • Severe flooding in Kanyama • Drought in Chazanga

The opportunities for the Water Trust arise due to the high levels of gender awareness in the community; the institutions recognise gender specific issues and there are high levels of involvement. New borehole legislation should improve the sustainability especially in Chazanga which is adversely affected by droughts. The main threats to Chazanga Water Trust are decreasing water levels, while for Kanyama Water Trust the risks are from flooding and resource contamination. The research found that the majority (10 out of 13) of technical applicants believe abstractions are not sustainable, principally due to a lack of regulation for abstractions or new boreholes. The most notable exception was the Acting Deputy Director of Water Affairs and Energy who believed there was sufficient water. This may create future supply issues in Chazanga as the River Kafue is also over abstracted. In Kanyama the shallow water table results in groundwater contamination and severe flooding impacts the distribution system and community. Chazanga is reliant on IWRM processes which regulate abstractions and supply, while as Kanyama is a downstream user they are reliant on upstream governance processes. However both Water Trusts are small and are affected by IWRM processes they have limited influence over. For example neither is mentioned in the Zambia IWRM National Plan produced in 2008[34].

5 Discussion

Based on the application of the benchmarking process and the literature review the research suggests that integrated water resource management is largely irrelevant to water supply in slums in developing countries. The principle reasons are due to the complexity and ambiguity of the concept and the difference in scale between service providers in slums and IWRM processes. At its simplest IWRM is a logical and appealing concept[35] and the principles are widely accepted. But it has no clear operational definition and the term is very broadly applied[36].The GWP now advocate that the 'integrated' in IWRM is short hand for the management approach it entails and could equally be described as holistic or systemic. As a result the practicalities of applying IWRM are often unclear to water providers. For example, both managers of the Water Trusts were unfamiliar with IWRM, but understood the principles of gender and participation. Secondly, lack of finance is a major limitation for both Water Trusts and to invest in a concept with little evidence of success makes it difficult to advocate the case of IWRM. Instead the authors think they should focus on doing what they understand as good water resource management.

Thirdly, the scale of IWRM processes makes it difficult for water providers to engage with IWRM, as it includes governments and regulators, whereas water providers in slums are often smaller and have their abstractions and discharges managed and regulated by other organisations. Likewise, a major limitation to action is a lack of appropriately decentralised finance[37]. Therefore they have little ability to influence the resource's management. For example, Chazanga Water Trust is affected by water shortages but has no control over the regulator. There lack of influence is partly due to the minimal impact they have upon the resource, as they work with the urban poor who only use very low volumes of water and typically have onsite sanitation. IWRM is more applicable to larger utilities that provide large volumes and sewerage, as domestic demand can be significant during the dry season and wastewater discharges can have a significant impact on water resources. Fourthly, IWRM reportedly doesn't work in informal economies due to capture by local elites[9],[21]. Lastly, the donor popularity of IWRM has declined, and been replaced with Water Safety Plans (WSPs). These provide a framework for identifying the risks to the water supply from catchment to consumer and should identify the specific risks to the water supply[38]. These have been developed specific for water providers and address the sustainability of supply, advocating that suppliers should take sufficiency of source water and alternative supply into account[38], minimising the need for IWRM implementation.

However there are situations when IWRM can be relevant to water providers in slums. Firstly, if there is a localised water resource, such as a small aquifer, service providers need to quantify their impact upon that resource. As if there is a high water table, their latrines risk polluting the aquifer. In this situation the providers need to establish management structures to protect the resource and deal with potential conflict (e.g. community water resource management[39]). Secondly, if supply is close to demand and water shortages are predicted for the area, the provider's abstractions may constitute a sizeable proportion of the withdrawals. In these situation increasing collaboration and participation will be central to reducing conflict, and water providers should engage with IWRM processes as the poorest are often the hardest affected (IRC provides details on engagement processes). Lastly, as water providers in slums generally supply disempowered water users and work with marginalised groups, they should engage with these groups whenever possible and represent their views in any existing participatory and collaborative processes.

In these situations the benchmarking process can provide a pragmatic method for applying the principles to ensure the resource sustainability, participation, gender awareness and cost recovery. Once an initial benchmarking has been complete the process can be extended to incorporate specific indicators for identified risks. The process is most applicable to small organisations as the questions have been developed for small scale operations. For larger organisations the principles are still relevant, although larger organisations are often more involved in other legal, institutional and management aspects of IWRM, as they consume larger volumes and there is often stricter regulation of the resource. Likewise the process is more appropriate in developing countries where IWRM processes and the governing and regulatory institutions are less developed, large proportions of the population are unserved and consumers have less influence over their supply. However, the process is only a list of questions and can only be used for diagnosing issues and highlighting areas of development. It does not provide information or encourage engagement with participation mechanisms or collaborative processes.

6 Conclusion

IWRM is extensively recognised as a good idea, but it can seem a confused concept to both policy makers and practitioners and it is criticised for lacking an operational definition and failing to sustain lasting change. It can be described as a synergy of sustainability, good water management, equity and collaboration. This research found that the ambiguity and complexity of IWRM and the difference in scale between water providers in slums mean IWRM processes are often not relevant to water suppliers. However, IWRM can be relevant if there is a small aquifer, water shortages or existing participatory processes. For these situations the most pragmatic approach is to apply local IWRM, applying the principles at the project level. That focuses upon encouraging stakeholder participation and community resource management. To ease the application of the principles a benchmarking process was developed, which converted the principles into questions to assess water resources and project management – the process emphasises better water management in the slums, not the process of implementing IWRM. The process can be used independently, but it will be more effective if it is incorporated into the water providers planning of projects. Alternatively Water Safety Plans can be implemented, as they are more relevant to water providers, specifically address water supply and have the advantage of increasing donor popularity.

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Appendices

The appendix consists of the following reports (page numbers of the reports have been modified:

- IWRM background report
- Zambia Climate Brief
- Zambia Climate Proofing
- Kenya Climate Brief
- Kenya Climate Proofing
- Madagascar Climate Brief
- Madagascar Climate Proofing
- Climate Change summary report
- IWRM Policy Briefing
- Climate Change Tender
- Climate Change Concept Note
- Climate Change Interview Guides

Appendix A: IWRM Background Report

Pragmatic but Principled

Background Report on Integrated Water Resource Management

Tom Heath
October 2010

Cranfield UNIVERSITY

WSUP
Water & Sanitation for the Urban Poor

This report explains the background and theory of Integrated Water Resource Management (IWRM), how it is implemented and synthesises the main criticisms. The document reviews how IWRM is relevant to the supply of drinking water and sanitation, urban areas and low income countries. Then reviews when IWRM is relevant to WSUP

This review is intended as an initial guide condensing the core aspect of IWRM, how it can be applied and the sector perceptions. For further information, refer to the key resource listed at the end of the document.

Summary

IWRM is about integrated and 'joined-up' management. It is about promoting integration across sectors, applications, groups in society and time, based upon an agreed set of principles. IWRM has been widely applied and aims for more coordinated use of land and water and is divided into full (wholly integrated activities) and light (applying the principles at the local level). The main criticisms of IWRM are the failure to translate the theory into action and the lack of change on the ground. There is a need for both light and full IWRM, but future projects need to increase participation and engagement.

Supplying domestic water and sanitation impacts other water users at abstractions (water demands can be can be very significant during the dry season and there is increasing competition for resources) and discharges (wastewater); an integrated approach can help remediate conflicts. IWRM has been neglected in urban areas, yet cites are a dominate feature within catchments and have complicated water environments and a large number of stakeholders. IWRM has been advocated in low income countries to address the millennium development goal, resulting in changes in law and policy; however, the changes have been superficial and had little real impact. For WSUP the process of IWRM is generally not very useful, but the principles are.

Background to IWRM

At its simplest Integrated Water Resource Management is a logical and appealing concept [1]. Its basis is that the many different uses of water resources are interdependent, and unregulated use of scarce water resources is wasteful and inherently unsustainable [2]. IWRM has emerged as an accepted alternative to sector-by-sector, top-down management approach [i] and the principles have been widely accepted as 'a good idea' [3]. Its popularity has been driven by the recognition of increasing pressure on water resources (and poor management and governance of water. The *Global Water Partnership* (GWP - the self appointed guardian of the concept) defines IWRM as a process which *"promotes the coordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital eco-systems[4]"*. There are various other definitions, but all contain the principles of equity (in terms of access to water resources and benefits), efficiency and environmental sustainability. IWRM emerged following the Earth Summits of 1992 and 2002, inspired by the sustainability agenda of the 1980s and 1990s (in particular the Bruntland report[5])[6], combined with the 1992 Dublin Principles[ii] (see box below). "*At its heart, IWRM is nothing more than the process of implementing them"*.

Box 1. The Dublin Principles 1992[7]

Principle 1: Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment

Since water sustains both life and livelihoods, effective management of water resources demands a holistic approach, linking social and economic development with protection of natural ecosystems. Effective management links land and water uses across the whole of a catchment area or ground water aquifer.

Principle 2: Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels

The participatory approach involves raising awareness of the importance of water among policy-makers and the general public. It means that decisions are taken at the lowest appropriate level, with full public consultation and involvement of users in the planning and implementation of water projects.

Principle 3: Women play a central part in the provision, management and safeguarding of water

This pivotal role of women as providers and users of water and guardians of the living environment has seldom been reflected in institutional arrangements for the development and management of water resources. Acceptance and implementation of this principle requires positive policies to address women's specific needs and to equip and empower women to participate at all levels in water resources programs, including decision-making and implementation, in ways defined by them.

Principle 4: Water has an economic value in all its competing uses and should be recognised as an economic and social good

Within this principle, it is vital to recognise first the basic right of all human beings to have access to clean water and sanitation at an affordable price. Past failure to recognise the economic value of water has led to wasteful and environmentally damaging uses of the resource. Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources.

[ii] The principles were agreed at the International Conference on Water and the Environment in Dublin. 1992.

Implementing IWRM

IWRM in effect calls for a broader systemic approach to water management. Implementing it can require reforms of water management laws, institutions and regulatory systems, and capacity building at a range of levels[3]. It aims for a more coordinated use of land and water, surface and groundwater and up and down stream users. The GWP provide guidance on the 'Why, What and How' of IWRM and believe successful implementation relies on three pillars[4]:

- An enabling legislative and policy environment which sets up and empowers
- An appropriate institutional framework composed of a mixture of central, local, river basin specific and public/private organisations, which provides the governance arrangements for administering
- A set of management instruments for gathering data and information, assessing resource levels and needs and allocating resources for use

More details on what each of these entails and example case studies is provided in the GWP toolbox[8] of good practice. The GWP describe the actual process of implementation as cyclical[iii] (Figure 1), emphasising it is an iterative, ongoing process. IWRM affects the management of water allocation, pollution control, monitoring, finance, floods, basin planning and stakeholder participation. IWRM has been applied at a range of scales and its implementation has been (artificially) divided between 'full' and 'light' IWRM[3]. Full IWRM concerns wholly integrated activities based on legislative, legal and institutional reforms that lead to implementing cross sector activities at a catchment scale.

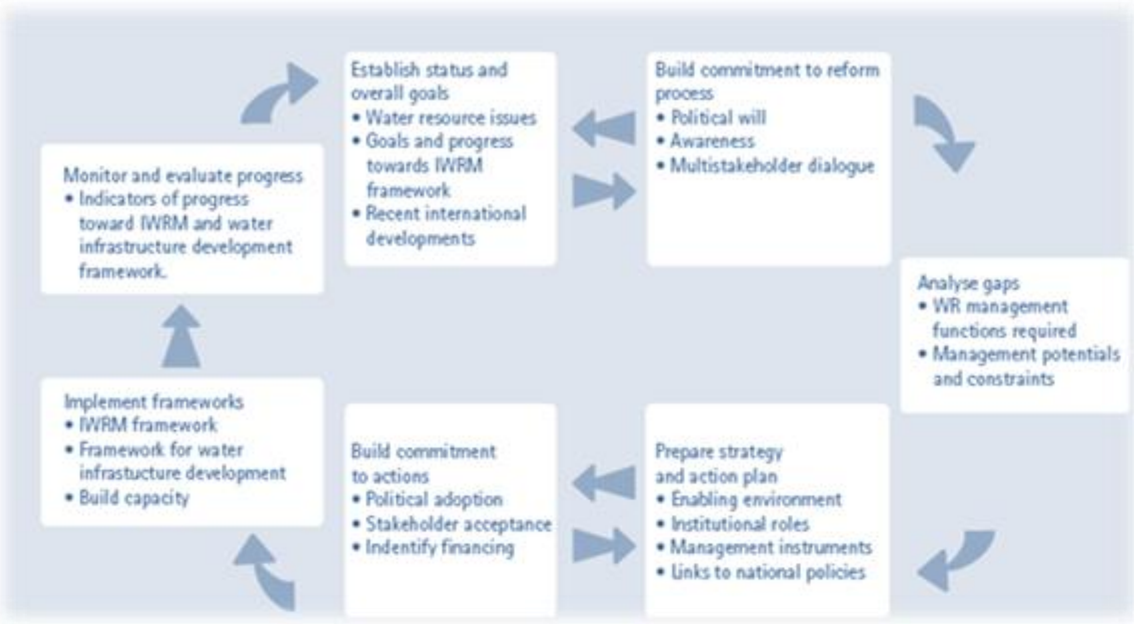

Figure 1 IWRM Process. Responds to changing situations and needs[9]

Light IWRM refers to the application of the Dublin principles by the individual or community within sub-sectors. It attempts to make it relevant at the community scale, where the over-arching legal and institutional framework is missing or ineffective. It aims to produce guidance for all stages of a project cycle, based on the logic that if all subsectors

[iii] The process is essentially a modified version of the standard decision making process model. It is an ongoing process

apply good IWRM at their own level this will lead to better local level water resource management. Light IWRM has been successfully applied at the village scale encouraging users to assess the impact of their action on other users and risks on a catchment scale[10,11]; however, the light process is less able to make the hard decisions required for water allocation and it is less prescribed as the process depends more on the individual's understanding. Table below outlines three examples of implementing IWRM.

What des it really mean?

"IWRM is about people (professionals and users) talking to each other more; about joint planning activities across sector boundaries; about integrated planning at the basin, but also at the community level. Critically IWRM is about information, and communication; about good planning based on a sound, and broadly based understanding of people's wants, and needs, but also their abilities and the constraints imposed by working with a finite resource[3]"

Experience of IWRM

The below table overviews the key component of each Dublin principles and synthesis results from an evaluation of 11 projects to identify the extent to which they incorporated the principles. 5 countries were from Africa, 5 Asia and 1 from South America.

Principle	Application (GWP)[124]	Lessons Learnt (1999)[13]
Fresh **water is** a **finite** and vulnerable resource, essential to sustain life, development and the environment	• Take holistic approach to management of water cycle • Recognise multiple use of water • Recognise limits of resource/consider water scarcity • Assess impact of human activities • Link up and down stream users • Promote integrated institutional approach	• Local communities can monitor and regulate their own catchments • Threats to water source and catchments recognised at all levels, but communities have limited understanding of cause and effect • Physical protection measures often limited to water source and did not include catchment • Unless government IWRM policies in place, catchment protection is unfocused and ineffective • Sustainable catchment protection and management requires a national framework • Interventions should be built on understanding of water catchment problems and local beliefs, customs and practice • Inefficiencies in water use may have several causes and there is little guidance on how to reduce them • People's 'view' of waste can sustain poor behaviours
Water development and management should be based on a **participatory approach**, involving users, planners and policy-makers at all levels	• Stakeholders should be part of decision making process • Participation is more than consultation (seek active engagement) • Empower ownership • Create participatory mechanism and capacity for community engagement • Make decisions at lowest appropriate level	• Good results achieved by involving communities in problem identification and solving • Stakeholders are more satisfied if decision making is transparent, but political or financial restriction reduce influence of stakeholders • Local initiatives can be strong but often lack capacity and orientation • Capacity building should be a priority, but it requires patience; learning is needed for effective engagement • Local tradition and skills are important assets • Governments are promoting decentralisation, back local government lack legal backing • Local authorities often lack resources while district and regional institutions lack management direction • Consultation for water resource allocation at a catchment level is not yet effective • Adequate water allocation can be agreed by stakeholders, using traditional and community based methods of water allocation • Conflict resolution mechanisms are not very effective
Women play a central part in the provision, management and safeguarding of water	• Involve women in decision making • Empower women into decision making roles • Consider gender roles	• National polices gradually favour a gender balance • Enabling environment for gender is promoted at local level (increased participation in water user committees) • Social pressure prevents women from fully participating • Focus on different roles of women and men proves positive • Gender equality is rarely achieved within implementing agency • Need to build capacity for women's involvement
Water has an **economic value** in all its competing uses and should be recognised as an economic and social good	• Water has a value an economic good that needs to be represented in the cost • Make subsidies transparent	• Willingness to pay depends on expected improvements • The economic and social value of water can be better recognised • Need to raise user awareness of investment and tariffs, enforce policies through payment incentives/penalties and adopt tariff variation for remote/poor areas or formally subsided users • Water is valued when it is scarce or because of tariffs

Criticisms of IWRM[iv]

There is a shared faith in the aims of integrated management, but despite some achievements and extraordinary investment, national governments have failed to sustain truly integrated programmes[14]. Thus IWRM is strongly criticised for failing to translate theory into action[15,16,18]. It lacks a clear operational definition and as such the implementation depends on the individuals involved, often the changes made are artificial and have little effect on the way water is used and managed on the ground. This is exemplified by interviews with IWRM practitioners of substantial experience who were unable to comprehensively define and describe the concepts and their purposes[17]. However, these failures are largely a result of the complex nature of the concept rather than failings of the practitioners - IWRM attempts to simultaneously address two highly complicated problems: sustainable development and cross sector planning[18]. Two recurring criticisms are (1) the lack of agreed indicators, making it difficult to compare and evaluate projects[19,20,21] and (2) that meaningful participation and engagement are missing[22] or the community lack the capacity to apply them[24].

Box 1: Main barriers to implementing IWRM[17]

Institutional: Effective water governance is crucial for the implementation of IWRM. Problems in management and governance go beyond mere technical challenges. In the case of IWRM, institutional reform is needed: correct policies, viable political institutions, workable financing arrangements, self-governing and self-supporting local systems. Institutions are rooted in a centralised structure with fragmented subsector approaches to water management, and often local institutions lack capacity. Awareness and priority of water issues at the political level is, in many cases, limited. Also information to support like what monitoring data sound management of water is generally lacking.

Evidence of success: The necessity of adapting the IWRM concept to suit different local contexts does not allow for a generic, complete description of strategies and techniques. In practice, the IWRM concept has not demonstrated its ability to increase the sustainability of water resources management. Empirical evidence is either missing or poorly reported. It will be important to identify the essential elements for IWRM, while avoiding rigid prescriptions and allowing for vast differences between individual situations

Ambiguity of definition: The most used definition of IWRM by the GWP gives very limited practical guidance to present and future water management practices. Besides the GWP definition, there are several other definitions that all differ from each other in one or more facets or dimensions. Ambiguity of definition further compounds difficulties in demonstrating success.

Complexity: IWRM takes into account relationships and dynamic interactions between human and natural systems, land and water systems, and key stakeholder agencies and groups. This interconnectedness on different scales and levels makes it very complex to translate the IWRM concept into practice. Management problems end up with ambiguous boundaries and complex links with other problems; goals, alternatives, and consequences that are not well defined or understood; pervasive uncertainty that may not be quantifiable; and iterative management that involves conflict and negotiation among multiple stakeholders with divergent interests and values.

[iv] The latest GWP publication (2010) provides a comprehensive review of the criticism of IWRM and responses. It also important to recognise that belief in IWRM is strongly divided betweens it advocates (principally the GWP) and its critics (mainly in academia).

Future of *IWRM*

> *"In many cases local agreement and capacity building on a better sharing and use will have greater impact than new national laws or international level treaties*[2]*"*

How can IWRM be used? The principles are accepted rational and it is clear IWRM is needed in WASH to incorporate the other sectors' needs. Yet how can real change be made on the ground? Biswas[v] one of the strongest critics of IWRM, advocates that what is needed is not integration but the fostering of collaboration, co-operation and coordination[23]. The latest GWP (2010) document[6] outlines lessons from 12 case studies highlighting the importance of higher level support (policy and institutions), that application will be specific to each society, there is not necessarily a contradiction between protection of the environment and economic growth and there is no 'magic bullet' for water management. A key recurring theme is effective management of water requires sustained and collective effort and engagement if it is to be successful.

A 2008 conference reviewing the implementation of IWRM in low income countries stated there is general agreement on the principles of IWRM, but there is a need for capacity building (particularly those lacking capacity to engage in decision making[24]), a greater focus on community level projects, integration of long-term water resource planning, more focused engagement, pragmatically working with city stakeholders (fostering joint planning and information sharing [24]), appropriate economic instruments and targets [25]. Results were presented from a joint project in South Africa (one of the first countries to apply IWRM nationally) that focused on moving towards decentralisation, capacity building and interactive learning. It concluded[6] that IWRM is no longer a thing to do but an interactive and emergent process of adaptive water resource management[vi]. Likewise, the GWP[6] (2010) now describes IWRM not as a prescription but a practical framework for addressing water management challenges (it is not an end in itself), outlining that 'integrated is short hand for the management approach it entails and could equally be described as holistic or systemic (*arguably the GWP's current emphasis on IWRM as synonymous with good water management could be considered as the GWP backtracking*). This approach was exemplified in the EMPOWERS[vii] project, which defined 7 principles for local water governance (Box 2). The local focus makes lighter approaches better suited to adapt and incorporate informal structures and institutions. Alongside this there has been a renew drive for infrastructure projects to compensate for the perceived ephemeral nature of IWRM[26].

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[v] He argues there is absolutely no evidence from anywhere in the world that it will work for macro- or meso-scale policies, programmes and projects on a long-term basis!

[vi] Adaptive management seeks to increase the adaptive capacity of basins based on an understanding of the key factors that determine the basin's vulnerability.

[vii] Euro-Med Participatory Water Resource Scenarios Project, aimed to improve long term access and rights to water for underprivileged populations in local communities in Egypt, Jordan and Palestine, within the context of local water governance under the principles of IWRM.

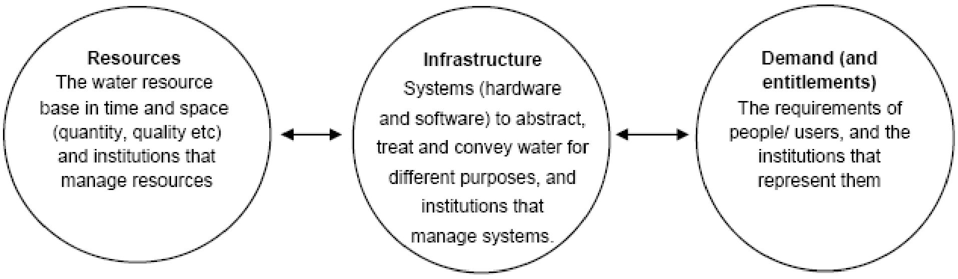
Box 2: Seven Principles for Local Water Governance[27]

1. Local water governance should be based upon the integrated participation of all stakeholders and end-users at all levels
2. Local water governance requires that special efforts are made to include vulnerable groups
3. Locally appropriate solutions and tools should be developed through the use of participatory research and action
4. Capacities of stakeholders should be developed at different levels to enable them to participate in water resource planning and management
5. Water information should be considered a public good; and access to information be enabled for all citizens
6. Awareness must be developed for informed participation in water governance
7. The efforts of all actors (government, partners in development, civil society) should be harmonised and contribute to achieving agreed and locally owned visions and strategies

There are a wide range of light projects (EMPOWERS[28], LoGo Water[29], SWELL,[30] WaterAid/Oxfam[31], WATERCOURSE[32], WHIRL[33]) whose methods focus upon community participation. The methods vary but the main components are working with community owned knowledge and existing institutions, identifying risk, focusing on capacity building, active learning, engaging with local stakeholders and empowering them to make decisions. Essentially they believe that fostering community ownership and local decision making improves the success of the project, using IWRM as a medium for fostering the exchange of ideas and commitments. Additionally the hope is that success at the local level encourages buy-in from larger organisations, increasing the influence of the project. Some of the key tools for bottom up approaches are outlined below:

- **Community Based Water Resource Management (Water Safety Plans)[3,11]:** Derived from water safety plans, the process aims to link local level IWRM principles to the operation approach set out by WSP. The process entails risk identification and management in partnership with the community and consists of three key elements: [1] identification of credible risks to water supply systems services; [2] prioritisation of risks (based on community's priorities); [3] establishment of controls to manage identified risks (at an appropriate level for community water supply management). The work has focused upon rural communities and typically entails communities monitoring water levels and rainfall, mapping water resources, risk assessment for the water supply and land management
- **EMPOWERS Guidelines, Methods and Tools[27]**: A document outlining tools for participatory learning and action; assessing; working with stakeholders; and monitoring. The document describes the objectives of each tool, the required materials and resources, overviews the method and lists tips and tricks.
- **NEWATER Training and guidance booklet for adaptive water management[34]:** Describes instruments and applications that are can address various steps in the IWRM process. The tools are intended to raise awareness, explore potential management scenarios and encourage engagement and the exchange of information between stakeholders.

- **Resources, infrastructure, demand and entitlements (RIDe)**[35]: A simple framework with generic application. It is based on the understanding that water resources are linked to people by supply (and disposal) infrastructure, and that each of these three system elements (resources, infrastructure, users) normally has its own set of institutions, boundaries and other characteristics



- **Water Audits (Water Accounting)[3]:** this is a pragmatic approach to assess water resources and demands. It is promoted as a key step for effective and sustainable IWRM. It is based on the principles that knowledge of the current status of water resources and demand trends is essential for success and an understanding of factors affecting access and entitlement is fundamental for engagement with the poor. It implies a holistic view and interaction with society
- **IWRM guidelines for Local Authorities (LOGO)**, Local Governments for Sustainability have produce guidance on IWRM specifically tailored for local governments in the Southern African Development Community. The outline the benefits , the role of local government and practical steps for engagement[29]

Relevance of IWRM

The following sections outline how the principles of IWRM are relevant to different sectors.

IWRM and Water and Sanitation

IWRM occurs at the intersection of the different water sectors (Figure 2). IWRM interacts with the domestic cycle at inlets (abstractions) and outlets (discharges) impacting other users and the environment. Abstractions require a reliable quantity of reasonable quality water, which needs to be protected from competing interests and pressurised 24 hours a day (to avoid leaky pipes), whereas discharges can pollute the source, especially when treatment is forfeited. IWRM can also be applied to smaller decentralised systems to ensure good practice within domestic supply. The main challenges affecting drinking water supply and IWRM are due to the following[3]:

- Scale: conflict is typically at a local level or resulting from a failure to consider downstream users
- Boundaries: conflict is created because administrative and riparian boundaries are not necessarily concurrent
- Temporal variability: Water demand is constant (slightly higher in summer) but 44444supply is variable

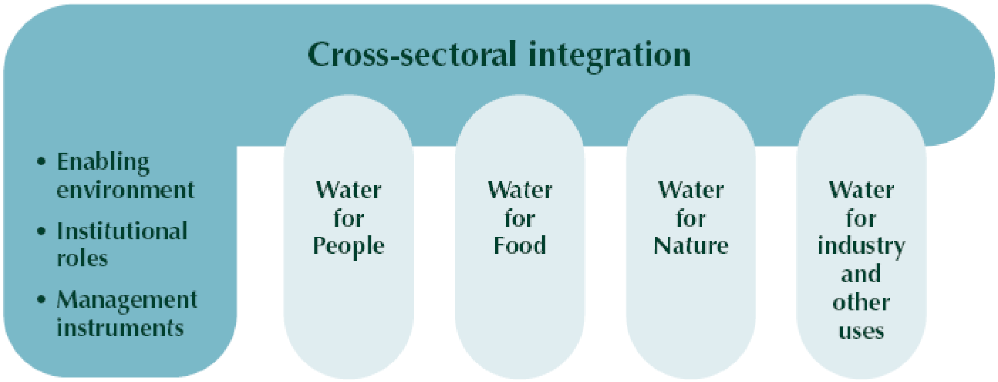


Figure 2: Cross-sector integration: the space for IWRM[4]

The various sub-sectors of the water sector can generally operate independently of each other without creating too many externalities[viii]. However, once demand is close to resource availability and the volume of polluted water rises, the need for a larger vision and integration effort is critical and IWRM provides an appropriate framework to address the challenges. Yet to date the WATSAN community has failed to engage adequately with IWRM[3]. Specific challenges and opportunities include:

- WATSAN demands are almost always given national priority, but the water demands are assumed to be trivial compared to other sectors; however, during dry seasons or droughts, they can represent a very significant share of the water resources
- WATSAN needs to shift from supply augmentation to demand management, as mechanisms to prioritise domestic water use often fail, due to increasing competition for resources as new sources are no longer available. As a result, the WATSAN sector increasingly has to compete for its water resource needs. This competition with other users can lead to conflict and increase costs, which IWRM can remediate
- Poor communities typically use water for multiple uses (backyard irrigation or keeping a few livestock) requiring 50-200 lpcd, significantly more than the expected 25-50lpcd. Multiple uses allow the diversification of livelihoods, improving income levels, health, and the sustainability of water systems (increasing both the willingness and ability of poorer communities to pay). IWRM provides a platform for discussing and managing multiple uses[36]
- Discharges can have major negative impacts on other sectors. IWRM provides a good framework for better understanding the issues and determining appropriate mitigation. Central to this will be accounting for downstream user's rights and the impact upon the environment of waste water. In particular, wastewater reuse for agriculture has become increasingly common and is associated with significant health risks both to farmers and food, requiring health hygiene education at the farm level and during food preparation [37]

[viii] A consequence of an economic activity that is experienced by unrelated third parties (can be either positive or negative)

- WATSAN affects 100 % of the population and thus is an entry point for increased participation in IWRM. It can provide the motivation and opportunity for individuals to get involved with IWRM and as utilities are already involved in service delivery they act as the obvious choice for representation.
- IWRM provides a framework for adapting to climate change, by building the capacity of countries to improve their ability to cope with today's climate variability[1,38,39]

IWRM and Urban areas

There has been little application of IWRM in urban areas, as it has been viewed as an issue for river basin management[40]. However, cities are dominant features within catchments and the need to consider the relevant activities (rural water supply, down-stream use, and agriculture) beyond the urban boundaries needs to be recognised[41]. At the city scale IWRM is relevant for addressing the complex sets of interdependent relationships existing within and between human and environmental systems, assessing the impact of all water-related urban processes on issues such as human health, environmental protection, water quality, water demand, affordability, land and water-based recreation, and stakeholder satisfaction. IWRM can be applied to urban areas to address the following negative externalities[42]:

- The negative externalities that arise from the uncoordinated use of water and land resources
- The opportunity costs of using water for low value/benefit purposes
- The benefits [costs] of a project or service may be limited [increased] by the failure to provide another service (e.g. water supply without hygiene /increased health cost if there is poor water supply)

Central to successful water management in urban areas is recognising the larger number of stakeholders than in rural areas, including those responsible for water supply and sanitation services, storm water and solid waste management, regulators, householders, industrialists, labour unions, environmentalists, downstream users and recreation groups. In urban areas these groups are typically fragmented in their roles and responsibilities and coordinating them of the main challenges[24]. In addition in urban areas there is often limited capacity to formal more participatory apaches and engage in decision making, related to limited access to and use of information on more integrated approaches[24].

IWRM in Low Income (IWMI AND 2010)

> *"there has been some recent improvement in the IWRM planning process at national level but much more needs to be done to implement the plans"*[43]

Low income countries have actively been encouraged to move from the traditional *supply-side orientation* towards *proactive demand management* under the broad framework of IWRM. However, what is usually implemented takes a narrow view of IWRM and tends to include a *blue-print* package including: [1] A national water policy; [2] A water law and regulatory framework; [3] Recognition of River Basin as the appropriate unit of water and land resources planning and management; [4] Treating water as an economic good; and [5] Participatory water resource management[44]. Several of these mark a significant shift from current paradigms and making this transition is proving to be difficult. Drafting new water laws is easy; enforcing them is not. Renaming regional water departments as basin organisations is easy; but managing water resources at basin level is not. Declaring water an economic good is simple; but using price mechanisms to direct water to high-value uses is proving complex. This is combined with a lack of political will to seriously engage in water policy change, limited financing and national resources for water related development, low awareness of water issues, weaknesses related to human and institutional capacity, and discontinued support programmes[40]. Consequently, IWRM initiatives in low income country contexts have proved to be ineffective at best and counterproductive at worst. This is further complicated by the large proportion of the water sector that is informal, depending upon self-provision, informal exchanges and local community institutions that are not under the direct influence of formal public institutions. This challenges the standard IWRM approach as the institutional and legal reforms struggle to account for the informal sectors[45]. Despite these challenges, IWRM is advocated to advance progress on the Millennium Development Goals (MDGs)[43], as it encourages the sound management of freshwater resources, supply of unpolluted water and environmental sanitation. The UN –Water and GWP produced a guide[46] for advancing IWRM processes, outlining potential indicators (Box 3).

Box 3: MDG potential performance indicators[46]

MDG 1: Poverty and Hunger

- Infrastructure to store surface water, and further develop groundwater resources, is put in place
- The health and productivity of aquatic ecosystems - in particular related to fish productivity - is optimized and protected;
- Rural poor populations are protected against flood risks

MDG 4-6: Health

- Discharges of human waste waters are treated for bacterial contamination to prevent diarrhoea outbreaks
- Toxic emissions from industrial enterprises are controlled within international health standards
- Pesticide release to groundwater, wetlands and surface water is controlled

MDG 7: Environmental sustainability

- Appropriate environmental flows are ensured, to maintain wetlands goods and services
- Safe water supply and sanitation expansion has reached or exceeded target 10
- Urban slum dwellers are protected against flooding
- Social, economic and regulatory instruments are changing inappropriate water allocations and uses
- Water conflicts across the sectors are mediated through participation of appropriate stakeholder groups

When IWRM is relevant to WSUP

This section outlines whether and when integrated water resource management (IWRM) is relevant to WSUP. IWRM is internationally recognised as a good idea, but it can seem to be a confused concept, to both to policy makers and practitioners. It is really a synergy of sustainability, good water management, equity and collaboration, but it is criticised for lacking an operational definition and failing to sustain lasting change. The following reviews the situations when IWRM is relevant to water supply and sanitation services in peri-urban areas, outlines why the process of IWRM is generally not relevant to WSUP then summarises the benefits of incorporating the principles into WSUP's work and how to do this.

IWRM is sometimes relevant to WSUP projects:

- If **there is a localised water resource** (e.g. small aquifer) WSUP need to ensure the local partners understand how they impact the resource and assess its sustainability, setting up management structures to protect the resource, deal with conflict and manage the supply. WaterAid and Oxfam[31] have developed a process for community water resource management that can be used as a guide.
- If **water shortages are predicted** for the region, and increasing collaboration and participation will be central to reducing conflict. WSUP should support IWRM processes as the poorest are often the hardest affected, although domestic supplies are generally protected and for large resources WSUP is rarely involved with the resource management. For example in Antananarivo during the dry season there is often insufficient water for irrigation and industry but drinking water supplies are guaranteed
- If WSUP are **capacity building the regulators and the institutions responsible for managing water resources**. They need to encourage them to be proactive in collaborating with all the stakeholders, ensure they engage in IWRM dialogues and get them in contact with the regional Global Water Partnership representative[47]
- If **WSUP are representing disempowered water users**. WSUP will often be working with marginalised groups who are overlooked or excluded from water resource dialogues. WSUP should engage with these groups to represent their viewpoints, though this will often be done during the implementation of the project. For example WSUP have represented the peri-urban communities in Naivasha (Kenya) during discussions about Lake Naivasha

However, IWRM is often not relevant to WSUP because:

1. **WSUP work with the urban poor** who only require a minimal proportion of the water available and typically have onsite sanitation. Therefore they have little impact on water resources - IWRM can be more relevant for larger utilities who provide large volumes and sewage (domestic demand can be significant during the dry season and wastewater discharges can have a significant impact on water resources)

2. **WSUP aren't mainly involved with the water regulators/managers of the resource.** IWRM focuses upon governments and regulators. The majority of reports are for governments (local and national) and regulators, and there is little information to support IWRM for local water service providers in peri-urban and informal areas. WSUP principally work with utilities and community organisations that usually have their abstractions and discharges managed and determined by other organisations. The exception is localised resources on which the abstractions and discharges for the urban poor may have significant impacts

3. **There is no clear operational definition for IWRM.** The meaning of IWRM is vague, it is described as good water management, but what this actually means in the WSUP context is unclear. Therefore WSUP should focus on doing what they understand as good water resource management, but with more emphasis on collaboration.

4. **It's not an appropriate use of resources.** WSUP are not the appropriate organisation to provide the training or facilitate the process, they don't have experience of IWRM and aren't involved with government level institutions, in addition the benefits to the urban poor would be marginal

5. The benefits of IWRM are fiercely contested; donors are more interested in water safety plans and IWRM reportedly doesn't work in informal settings

In summary, the process of IWRM is generally not very useful to WSUP, but the principles are. The principles have been converted into benchmarks to measure water management and environmental sustainability, developing an audit tool[48] to assess water resources and project management – the tool emphasises better water management in the slums, not the process of implementing IWRM. This can be used independently, but it will be more effective if incorporated into the WSUP scoping assessment of projects.

For the situations when IWRM is relevant, the most pragmatic approach is to apply "light IWRM", applying the principles at the project level. This should bring about meaningful stakeholder participation, community resource management and bring together the key partners to improve the safety of the water. Applying the environmental sustainability audit will help establish a basic framework for addressing the issues. In addition, the tools outlined in the future of IWRM are relevant and WSUP should consider implementing Water Safety Plans[49]. These provide a framework for identifying the risks to the water supply from catchment to consumer and should identify the specific risks to the water supply associated with the above situations. Water Safety Plans are much more relevant to WSUP than exploring any IWRM process, as they specifically address water supply.

Resources

Primary:

- **IRC Thematic Overview Paper on IWRM and Water Supply (2004)[3]**. This is an excellent review of IWRM specific to the water sector, it is short and concise and list further reading and resources.
- **IRC links**: Description of key IWRM past and current projects http://www.irc.nl/page/16388 websites http://www.irc.nl/page/10676 and resources http://www.irc.nl/page/10677
- **IWRM in practice (2010)[6]:** The most recent publication from the GWP describes 12 case studies summarising the key lessons and experience. It considers practical examples, looking at how IWRM has contributed at different scales and reviews criticisms and the future of IWRM

Secondary:

- **EMPOWERS Guidelines, Methods and Tools[28]**: A document outlining tools for participatory learning and action; assessing; working with stakeholders; and monitoring. The document describes the objectives of each tool, the required materials and resources, overviews the method and lists tips and tricks.
- **GWP Toolbox:** The GWP is an international network created to foster IWRM. The toolbox is a series of tools and case studies for implementing IWRM. However some of the tools have limited information and how they would be applied is unclear. There is also an online library of key papers and other resources, and links to a wider range websites and related partners. www.gwptoolbox.org/
- **IWRM Critique** Three insightful papers critiquing IWRM:
  - IWRM: A Reassessment - Problems with the definition and concept of integration[23]
  - From Premise to Practice – Reviews the difficulties in implementing IWRM[18]
  - IWMI Water Policy Briefing 24 - Review how IWRM is typical applied in developing countries[36]
- **IRC Integrated Water Resource Management in Water and Sanitation Projects** (1999)[13] Review of 11 drinking water and sanitation supply (DWSS) and integrated water resource management (IWRM) projects from around the world. It examines their successes and failures and draws lessons for the implementation of IWRM strategies elsewhere.
- **LoGo WaterError! Bookmark not defined.**, Assessed the role of local governments in IWRM in Southern Africa., in particular the set of materials for local governments
- **NEWATER Training and guidance booklet for adaptive water management[34]:** Describes instruments and applications that are can address various steps in the IWRM process. The tools are intended to raise awareness, explore potential management scenarios and encourage engagement and the exchange of information between stakeholders.
- **SWITCH Project[24]** Overview the institutional side of integrated water management, looking at governance issues and learning alliances
- **Water SA 34 (6)** (2009) This is a special edition of the journal based on a conference on implementing IWRM, the papers are positive on IWRM and highlight successfully participation and examples. Refer to Anderson et al., 2008[25] for a synthesis of the presentations

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Appendix B: Zambia Climate Brief

ZAMBIA CLIMATE CHANGE BRIEFING

Temperature

The mean temperature is predicted to increase in Zambia with a greater frequency of 'Hot' days and nights and very few 'Cold' days or nights

Rainfall

Changes in rainfall are less certain, but rainfall is expected to decrease especially in the winter season, and increase in intensity – increasing water scarcity

Extreme Events

An expected increase in the frequency and intensity of extreme events, primarily droughts and floods. Expect extreme events to occur in new locations and a shorter growing season in some regions

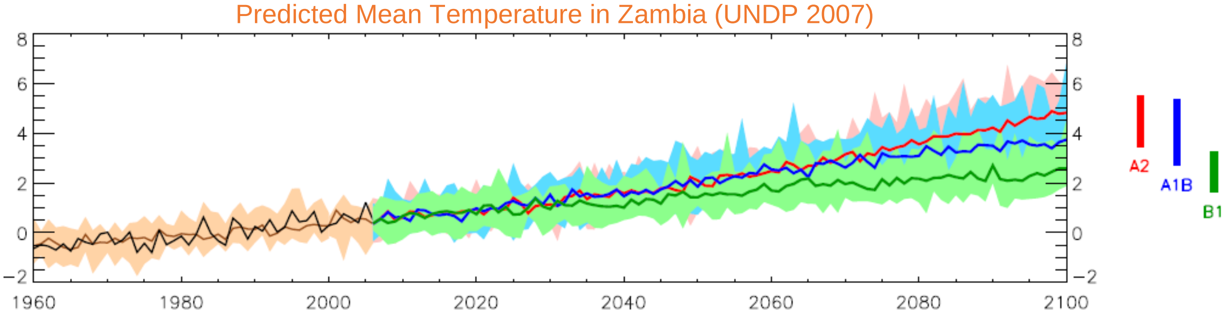
Overview

Zambia has a tropical climate, although temperatures remain relatively cool, due to the high East African Plateau. There are three seasons: a cool, dry winter from May to September; a hot, dry season in October and November; and a rainy season, which is even hotter, from December to April. The annual rainfall averages between 700 mm in the south and 1,400 mm in the north. Zambia has extensive water resources, the sum of which far exceeds the consumptive use - even in a drought year. However, there are significant variations across the country, and a strong seasonal distribution leading to water deficits.

Climate Change

Observational evidence from all continents and most oceans show that many natural systems are being affected by climate change, particularly temperature increases. The mean temperature in Zambia has steadily increased over the last 40 years, as shown on the graph below. The graph also synthesises the mean temperature predicted by 22 global climate models, their range is indicated by the shading and the lines refer to three emissions scenarios A2 (high), A1B (medium) and B1 (low) (describe future economic growth and energy). The change in climate between 1960 and 2003 and the climate changes predicted by 2060 and 2090 are summarised in the table below.

Predicted Mean Temperature in Zambia (UNDP 2007)



	Observed (between 1960 and 2003)	Changes Predicted by Global Climate Models by 2060	2090
Temperature Rise[1]	1.3°C (0.29 per decade)	1.2 - 3.4°C	1.6 - 5.5°C[2]
Frequency '*Hot' Days*[3] (% of days)	12% of days	15 - 29%	16 - 49%
Frequency of '*Hot' Days* based on current climate (% of days)	N/A		22 - 80%
Frequency '*Hot' Nights* (% of days)	17% of days	26 - 54%	30 - 80%
Frequency of '*Hot' Nights* based on current climate (% of days)	N/A		30 - 99%
Frequency '*Cold' Days*[4] (% of days)	-6% (22 days)	1 - 4%	0
Frequency '*Cold' Nights* (% of days)	-10% (35 day)	1 - 4%	0
Precipitation	-1.9mm per month (2.3% per decade)[5]	No large changes	
Heavy Rainfall Events[6]	Possible decrease (not statically significant)	Increase annually, but mainly in rainy season	
Maximum 1- and 5-day rainfalls	Possible decrease (not statically significant)	Increase in magnitude in rainy season	

[1] The projected rate of warming is a little more rapid in the southern and western regions of Zambia than the northern and eastern regions
[2] The maximum temperature range for any of the models is no more than 1.5- 2.5°C for each emission scenario
[3] 'Hot' day or 'Hot' night is defined by the temperature exceeded on 10% of days or nights in the current climate of that region (average)
[4] 'Cold' days or 'Cold' nights are defined as the temperature for the coldest 10% of days or nights (average)
[5] This annual decrease is largely due to decreases in the rainy season, which has decreased by 7.1mm per month (3.5%) per decade
[6] A 'Heavy' event is defined as a daily rainfall total which exceeds the threshold that is exceeded on 5% of rainy days in the current climate of that region

WSUP Water & Sanitation for the Urban Poor

Cranfield UNIVERSITY

MAIN IMPACTS OF CLIMATE CHANGE

The consequences of climate change are likely to increase the number of forced migrations (due to undermined livelihoods – primarily due to food insecurities). The migrations will typically be to urban areas, where the migrants are often more rather than less vulnerable to certain climate-related impacts. The increased populations in urban area will increase competition over natural resources and the likelihood of conflict. In addition, resource scarcity can lead to increased capture of resources by elites exacerbating existing inequalities.

	Droughts	Floods	Extreme Heat	Shorter Rainy Season
Water	• Water scarcity • Reduced water quality (reduced dilution of contaminants) • Lower ground water • Sewage in rivers less dilute	• Contamination of drinking water (in particular cholera)[°] • Ingress of groundwater into pipes	• Reduced water quality • Higher water temperatures exacerbate water pollution	• Lower water levels
Food	• Crop damage/loss leading to food scarcity and hunger[Σ] • Decrease in cattle population • Decreased nutrients reduce fish stocks (commercial species in particular – breams and sardines most vulnerable)[+] • Increased soil erosion and decreased soil fertility • Increased honey and wild flower production (if drought is not too severe)[Ω] • Drying and desertification • Degradation of grasslands	• Crop damage/loss, leading to food scarcity and hunger[Σ] • Loss of crop land and grazing ground [Σ] • Life loss (humans and livestock)	• Loss of life (animals and humans) • Crop damage/loss[Σ] • Decreased nutrients reduce fish stocks (commercial species in particular) [+] • Decreased livestock feed	• Increase in risk of crop failure[Σ] • Crop damage/loss • Crop seeds do not reach maturity (which negatively affects the next crop generation) • Maize won't mature (It is the main crop for 80% of the population)
Infrastructure	• Insufficient water for hydroelectric[Π] - power shortages • Increased energy demand for cooling	• Destruction of infrastructure (houses, roads, water facilities) • Interference with energy production due to change in water flows	• Insufficient water for hydroelectric - power shortages[Π] • Exaggerated heat island effect (i.e. increased temperature in urban areas)	
Health	• Increase in diseases (affecting humans and animals) • Less water for hygiene and cleaning	• Loss of life • Increase in diseases (malaria, dysentery, cholera, etc.)	• Loss of life • Increase in diseases affecting animals, crops and humans (potential decrease in malaria) • Decreased human capacity to do work • Worsening air quality	
Income	• Income Loss • Women and children use more time for chores • Reduction in *Moimbo* woodland* regeneration • Animal migration and stress	• Income Loss • Disruption of communities	• Income Loss • Forest Fires • Reduction in *Miombo* woodland* regeneration • *Kalahari* woodland[¥] destroyed • Animal migration and stress	• Decreased income from crop selling for those with reduced production

**Miombo* woodland cover 60% of the land and provides fuel and charcoal for 80% of households, equivalent to 4.3 million tonnes of wood, providing 70% of the nations energy needs

[+] Zambia holds 40% of the water in the South African Development Community region, which many communities across the nation depend on for fishing & livelihoods

°The 2005 flood resulted in 5,000 recorded cases of chorea in Lusaka

[¥]*Kalahari* Woodland (deciduous trees and short grasses on sand) is present in western area and is used by Angolan immigrants who rely on it for cultivation of cassava

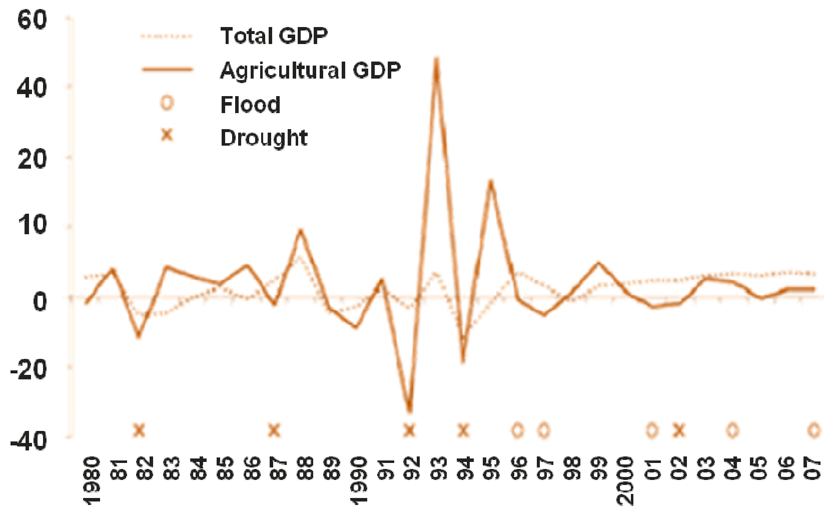
[Π]Hydroelectricity contributes 14% of total energy use, but represent 92% of installed capacity and accounts for 99 of electricity production, key for industry and mining

[Σ]The area suitable for maize production in the North and centre is likely to decrease by 80%, while maize yields with decrease by 66% (16% irrigated land – 5%)

[Ω]Honey production is expected to be a significant growth sector in the economy

Importance of Climate

The variability of weather has a large effect upon Zambia's GDP. The graph opposite illustrates the impact of floods and droughts upon the GDP. For example during the droughts of 2004/05 1.2 million people were in need of food assistance, while during the flood of 2006/07 400,000 people needed food aid for a period of 8 months. The relationship is due to Zambia's dependence on rain fed agriculture – primarily maize. A model was developed by the International Food Policy Research Institute (2009) assessing the impact of climate variability and changing climate on crop yields. The work highlighted that climate variability has a very significant role for economic development. For example the model estimated that during a severe drought (such as the 92/93 drought) GDP is reduced by US$ 2.6 billion and absolute poverty increases by 836,000, while a severe flood (such as the 06/07) reduces GDP by US$ 0.9 and increases absolute poverty by 273,000. The study concluded climate change may further exacerbate the negative consequences of climate variability, but the impacts of climate variability will dominate until 2025. Highlighting the need to invest in irrigation and water management practices, which mitigate the adverse impacts of climate change.



Zambia has **abundant water resources** (the highest in the region), but seasonal and temporal rainfall patterns and limited investment in infrastructure means the country still experiences **water scarcity and severe floods**. The main challenges of climate change are the reduction in *Miombo* woodland and maize yields**,** which will exacerbated by the high levels of poverty in the country

Vulnerability

A range of global and regional studies have assessed Zambia's vulnerability to climate change using global datasets[1,2,3,4,5] producing Indices for each country to enable simple comparison. The table below presents the scores (measure of vulnerability) for Zambia for 9 global indices. The indexes which assess the impact of climate change on water resource indicate that Zambia has a very low vulnerability; this is due to Zambia's relative abundance of water resources. However, when social factors are assessed (including Zambia's level of economic growth and governance) Zambia comes out with a medium vulnerability. This is due its limited adaptive capacity and widespread poverty in the country.

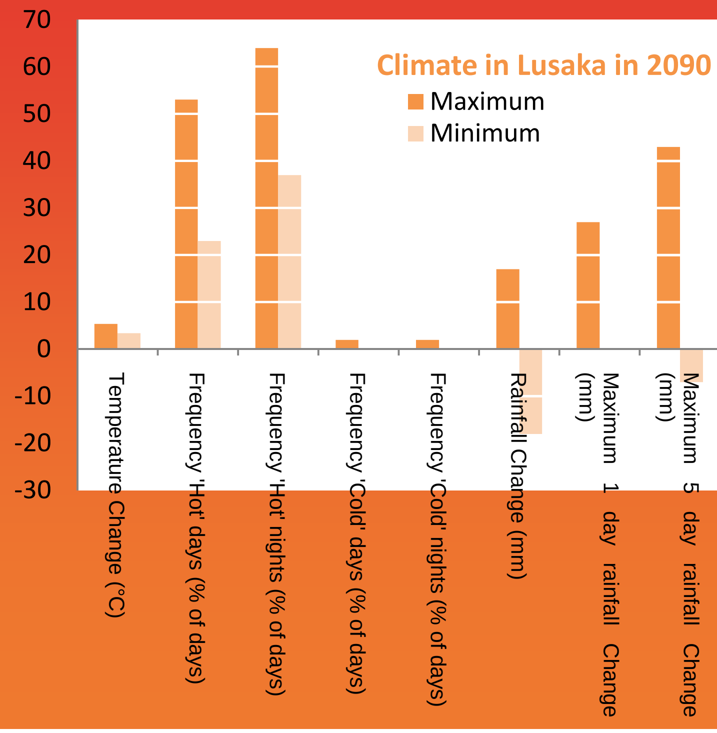
Index	Score	Vulnerability	How it's calculated
Water Resources			
Water Scarcity Index (2004)[1]	0.0027	Very low (Abundant)	Water extracted from rivers divided by the low flow (q90). E.G If ≥ 1 then consumption exceeds supply
Ground Water Dependence (2004)[1]	0.0402	Very low (Abundant)	Ground water withdrawn as a fraction of total water withdrawn in region
Total freshwater withdrawal as percentage of total renewable freshwater resources (2009)[2]	1.7%	Very Low	Total freshwater withdrawn in a given year, expressed in percentage of the total actual renewable water resources It is an indication of the pressure on the renewable freshwater resources. (data from 1998-2002)
Annual Renewable Water Supply per Person (Projections for 2025)[2]	>4000 m^3pp	Abundant supply	Runoff (data from 1950-2000) divided by Population (2025) (prediction from UN population division
Social Vulnerability			
Human Vulnerability (2007)[3]	0.597	29th /49 (Africa)	Social vulnerability to climate change (the Index consists of 5 weighted factors, each of which is scored). The factors are: economic well being and stability (20%), demographic structure (20%), global interconnectivity (10%) and dependence on natural resources (10%); HVB also includes institutional stability and infrastructure (40%) – corruption
Human Vulnerability (including corruption) (2007)[3]	0.631	42nd / 49 (Africa)	
Sensitivity and Adaptability (2007)[4]	0.481	164th / 182 (global)	Human Development Index (used as generic indicator for adaptive capacity)
Sensitivity Index (2004)[1]	2.33	Low	Combination of Water Scarcity Index, GW Dependence and Sensitivity and Adaptability Index
Climate Vulnerability Index (2007)[5]	-	Medium	The index links water resources modeling with human vulnerability assessments to contribute to a meaningful assessment for generic use

[1] Petra Döll (2009) Vulnerability to the impact of climate change on renewable groundwater resources: a global-scale assessment. *Environmental Res. Letters* 4 (3)
[2] World Business Council for Sustainable development Global Water Tool (2009) www.wbcsd.org/templates/TemplateWBCSD5/layout.asp?type=p&MeuId=MTUxNQ&doOpen=1&ClickMenu=LeftMenu
[3] Vincent, K. (2004) Creating an index of social vulnerability to climate change for Africa, Tyndall Centre Working Paper 56
[4] Human Development Index (2009) http://hdr.undp.org/en/statistics
[5] Centre for Ecology and Hydrology (2007) Oxford Centre for Water Resources. The Climate Vulnerability Index. http://ocwr.ouce.ox.ac.uk/research/wmpg/cvi/

Climate Impacts: Lusaka

Lusaka has a population of 2 million (2005) with a growth rate of 3.6%, 40% of residents live in informal areas – these unplanned areas have an estimated growth rate of 12%. Lusaka is in the central part of the country, which is the most populous zone and has the highest agricultural potential. The figure opposite overviews the changes to climate predicted to occur by 2090. The predictions show similar trends to the national predictions with rising temperatures, an increasing number of 'Hot' days and uncertain rainfall changes. Notwithstanding this, there is an anticipated decrease in volume of rainfall, and an increase in intensity.

The main water provider is Lusaka Water and Sewage Company (LWSC) (producing 94 million m^3 per day). Half the water is extracted from the Kafue River and the other half from groundwater, which is over extracted, increasingly polluted and boreholes are increasing drying up during droughts. 55% of the water from LWSC is unaccounted for and only 30% of consumers have piped sewers. In the informal areas there is indiscriminate groundwater extraction. WSUP target areas are Chanzanga and Kanyama, where water is provided directly by LWSC and through Water Trusts alongside private and NGO supplies.



- **Chazanga** (population approximately 35,000) is located on hilly terrain and is drained by three rivers. It can be divided into the new (planned and relatively spacious) and old (unplanned) areas. It is supplied by 4 boreholes (the water table is between 40-60m), which are operated by electric and hand pumps. There are also shallow wells which are not used for drinking
- **Kanyama** (population approximately 96,000) is located on an old wetland in a depression of flat hard rock (difficult to dig - constrains pit latrines), with a relatively high water table (6m) supplying 2 boreholes

	Chazanga	Kanyama	Predicted Impacts of Climate Change
Waste Management	Relatively clean, working waste management scheme. However, Lusaka waste dump is within 50 m of the 2 main boreholes	Poorly functioning waste management scheme. Households burn waste or dispose in pits (which collect water in the rainy season)	Flooding will spread waste and increase the risk of disease
Drainage	Good drainage and clear roads, but threatened by expansion	Poor drainage, drains blocked by housing, leads to water logging	Intense rainfall will increase severity of floods. A lower water table will improve drainage
Sanitation	Pit latrines*, spacious, some latrines within 30 m of boreholes	Pit latrines*, unlined, regularly flood when full	Flooding will lead to contamination of latrines and water supplies
Water Kiosks	27 water kiosks, majority leak or waste water and have no meter	112 Kiosks metered and well managed	Flooding damages facilities, during drought expect water scarcity[¥], this is likely to increase prices leading to vandalism and corruption
Water Quality	Tube wells reasonable quality but some are compromised by pollutants	Borehole meets WHO guidelines on drinking water quality. Shallow wells are contaminated, 40% population uses these for drinking water	Floods will contaminate source, droughts will increase water scarcity. Potentially higher water tables in winter lead to ingress of groundwater in pipe networks

*When the latrines are full, new latrines are dug. When there is no space occupants empty latrines onto road or next to latrine and wait for next flood to wash away pile

[¥] Chazanga will suffer from greater water scarcity due to the limited capacity of infrastructure and low yielding boreholes

Key References:

- **DFiD Guidance Sheets on Climate Change (2010 - Draft):** *Key sheets that summarise the existing guidance available on the implications of climate change for various strategic, sectoral and thematic policy issues (prepared by Cranfield University and the University of Sussex)*
- **IFPRI Paper 00890 (2009)**: The Impact of Climate Variability and Change on Economic Growth and Poverty in Zambia Available at: www.reliefweb.int/rw/RWFiles2009.nsf/FilesByRWDocUnidFilename/VDUX-7WDTAM-full_report.pdf/$File/full_report.pdf
- **IPCC**: **Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability**: Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Available at: *www.ipcc.ch/publications_and_data/ar4/wg2/en/ch9.htm*
- **IMF Zambia Poverty Reduction Strategy Paper (2002):** Available at: www.imf.org/external/np/prsp/2002/zmb/01/
- **UNDP Climate Change Country profiles (2010):** Analyses of up-to-date observed data and multi-model scenario-based projections. Providing observed and IPCC AR4 model data based on data from 23 different GCMs. Available at: country-profiles.geog.ox.ac.uk
- **Zambia. Initial national communication under United Nations Framework Convention on Climate Change (2004).** Ministry of Tourism Environment and Natural Resources. Available at:www.adaptationlearning.net/sites/default/files/zambia_inc.pdf
- **Zambia: National Adaption Plan for Action (2007)**: UN supported process to identify priority activities and immediate needs with regard to adaptation to climate change. Available at: www.preventionweb.net/files/8581_zmb01.pdf

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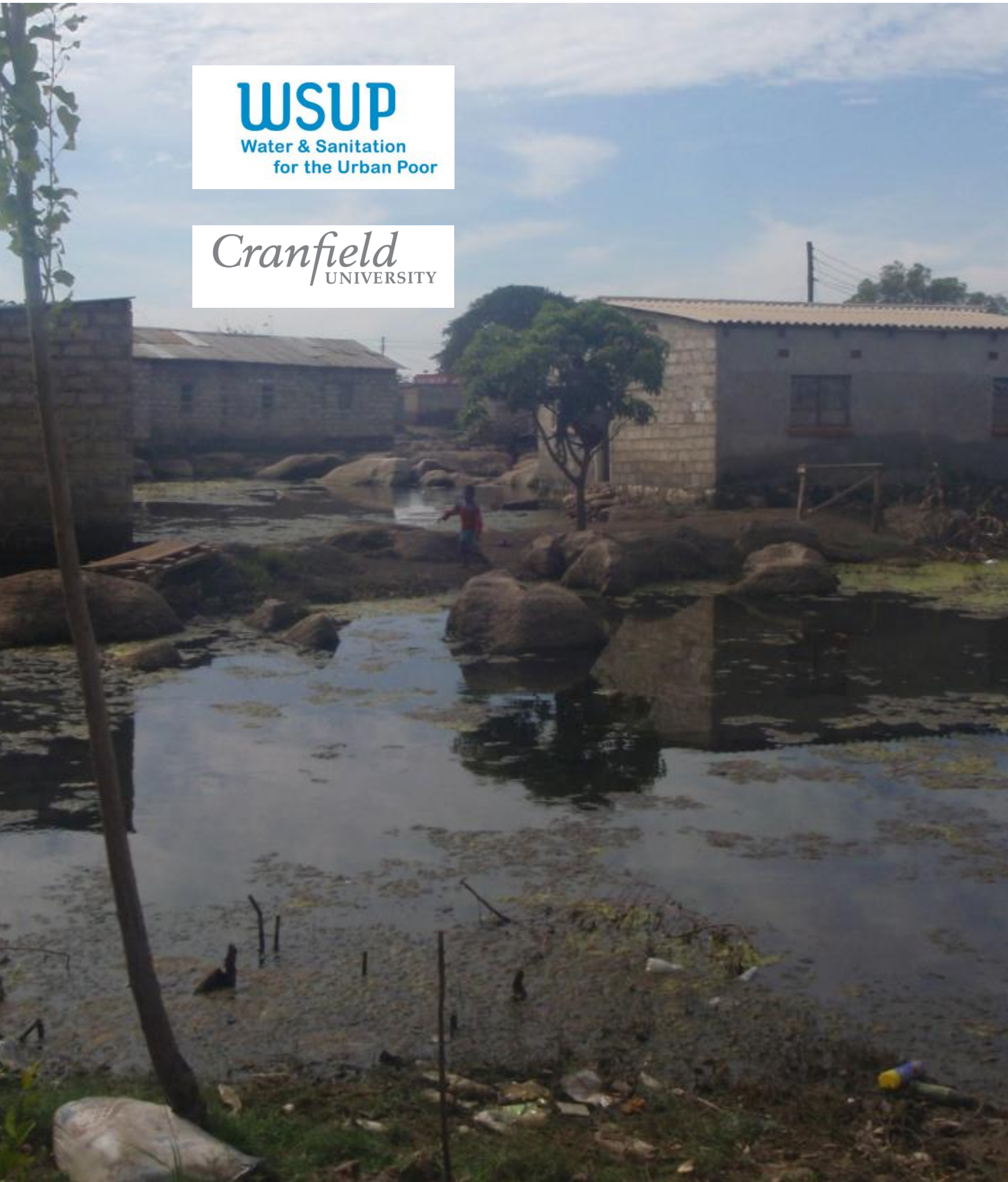
Appendix C: Zambia Climate Proofing

How to Climate Proof Water and Sanitation Services in the Peri-Urban Areas in Lusaka

WSUP
Water & Sanitation for the Urban Poor

Cranfield UNIVERSITY



How to Climate Proof Water and Sanitation Services in the Peri-Urban Areas in Lusaka

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Work based on field visit to Lusaka undertaken in May 2010

Cover Photo: Tom Heath 2010

Reference
Heath, T., Parker, A., & Weatherhead, E. K. (2010). How to climate proof water and sanitation services in the peri-urban areas in Lusaka. Report prepared by Cranfield University. WSUP, London.

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Executive Summary

This report evaluates the impacts of climate change on water and sanitation technologies in two peri-urban areas in Lusaka, Chazanga and Kanyama, and the potential adaptations required to mitigate the impacts. Under current forecasts of climate change, the mean temperature in Zambia is predicted to increase. It is less certain how average precipitation will be affected, but both floods and droughts will occur more often.

- **Chazanga** is most at risk to a decrease in precipitation which will cause a lower water table. This will result in water scarcity, damage to infrastructure and drying up of shallow wells, all of which will increase the demand for new kiosks. In addition, decreased rainfall will affect hydroelectricity generation and cause power shortages. However, if precipitation (or its intensity) increases, there will be flood damage to boreholes, kiosks, septic tanks and pit latrines and poor drainage at kiosks.

- **Kanyama** is most at risk to an increase in precipitation, resulting in an increase in flooding (currently Kanyama's floods last for 3 months). Flooding causes kiosks and buildings to collapse, contaminates water supplies (particularly the shallow wells used in the unserved areas) and affects livelihoods, education and health. Flooded latrines and contaminated water will increase cholera and diarrhoea.

Potential short, medium and long term adaptations were identified for the Water Trusts, Lusaka Water and Sewage Company and the City Council. The adaptations were determined based upon a field visit, a vulnerability assessment and a literature review. The key recommendations are as follows and should be developed within a water safety plan:

Chazanga:

- In the short term acquiring a generator to mitigate the impact of power cuts, while on a longer time scale acquiring a direct line from LWSC
- Expanding the kiosk network into unserved areas
- The building standards of soakaways should be improved
- Vegetation should be planted next to the roads and the shallow wells protected from runoff
- ECOSAN should be encouraged, investing in the technology , education and market for sewage
- There should be enforcement against fly tipping of faeces and raising awareness of the health issues

Kanyama:

- Improving the drainage should be the main priority
- Developing emptying options for latrines, including those which have collapsed
- Ensure new latrines are sufficiently elevated to avoid sewage out flowing
- ECOSAN should be reviewed and in the longer term decentralised sewage promoted
- Expand the kiosk network into unserved areas
- Tighter enforcement against fly tipping

Lusaka Water and Sewage Company:

- Investigate link between groundwater recharge and rainfall intensity in Chazanga
- Construct new storage tanks for both settlements
- Rehabilitation of pipe network to improve pressure in systems
- Establish/expand peri-urban unit to provide technical and administrative assistance during flooding

Lusaka City Council:

- Implement land management activities to reduce severity of floods
- Improve drainage system in Kanyama and employ workforce to maintain and clean the drains
- Subsidise tanker/provider free removal of waste, improve solid waste disposal options

- Construct a deeper and wider main drain in Kanyama to accommodate the increased flooding water

Contents

Introduction

"Observational evidence from all continents and most oceans shows that many natural systems are being affected by climate change, particularly temperature increases" (IPCC, 2007). This report outlines the impacts (both direct and indirect) associated with the climate scenarios predicted (both increasing and decreasing rainfall) for two peri-urban compounds in Lusaka – Chazanga and Kanyama.

It starts by reviewing the impacts of the climate scenarios predicted for Lusaka, on Chazanga and Kanyama; the indirect impacts of climate change and the impact upon water resources in Lusaka. It then synthesises how the climate scenarios will affect the existing vulnerabilities, problems and technology in Chazanga and Kanyama. The report concludes by outlining the main adaptations required in the peri-urban areas by the Water Trusts, Lusaka Water and Sewage Company and Lusaka City Council, dividing them between short, medium and long-term adaptations. The key climate resources for Zambia and ongoing climatic research in Zambia are also summarised.

The report aims to provide pragmatic recommendations for adaptation; focusing upon what is known rather than the uncertainties. The document should be read alongside the Zambia Climate Briefing (Heath, 2010).

Method

Prior to the fieldwork, key literature on the impacts of climate change on water and sanitation technologies was identified. The key document was a review completed by the WHO and DFID in 2010 (Charles *et al*., 2010). This describes the vulnerabilities of various water and sanitation technologies to climate change, and proposes adaptations. From the field visit it was possible to select which technologies are being used in Chazanga and Kanyama and hence identify the vulnerabilities of the whole water and sanitation system to climate change. The adaptations required to mitigate these vulnerabilities were also selected from Charles et al (2010) and are listed in the appendix.

The field visit to Lusaka, was completed in May 2010 and entailed 41 semi-structured interviews with members of the community and representatives from the local service providers, water utility, City Council, government, the scientific community and NGOs (Table 3 in the appendix lists the interviewees). The interviews and observations assessed the impact of flooding and droughts on the existing environmental, social and economic vulnerabilities and the impact on technologies. The interviews also assessed the institutional awareness of climate risks. Further climate vulnerabilities were identified from the literature review. One focus group was undertaken to do a cause and effect analysis (i.e. what are the problems, what causes them and what impacts they have).

The information gathered from the interviews was used to prepare a vulnerability assessment. This involved listing the problems identified in the peri-urban area and identifying the linkages between them (e.g. vehicles driving over pipes leads to leaks, which results in ingress of water). Once the linkages between all of the problems had been identified, the expected changes in climate were added (e.g. increasing rainfall) and the factors they impacted were identified. In addition, the indirect impacts of climate change (e.g. reduction in *Miombo* woodland) were incorporated assessing which factors they affected. This made it possible to assess how climate change will affect the existing vulnerabilities in Chazanga and Kanyama (see Appendix). This diagram was then used to determine the adaptations required to mitigate the problems.

The adaptations from both the fieldwork and the literature review were then amalgamated and assigned to the Water Trusts, Utility and City Council, dividing them into short medium and long term adaptations.

Impacts of Climate Change on the Peri-Urban Areas

Zambia has abundant water resources (40% of the SADC region's water) but a combination of seasonal and temporal rainfall patterns and limited investment in infrastructure means the country still experiences water scarcity as well as severe floods. The main climate change challenges facing Zambia are an expected increase in floods and droughts combined with a reduction in *Miombo* woodland and maize yields, which will exacerbate the high levels of poverty in the country. The main climate impacts expected are as follows (refer to the Zambia Climate Briefing (Heath, 2010) for a more comprehensive overview):

Climate Changes

- Temperature: the mean temperature is predicted to increase in Zambia with a greater frequency of 'Hot' days[1] and nights and very few 'Cold'[2] days or nights
- Rainfall: changes in rainfall are less certain, but rainfall is expected to increase in the rainy season and the winter is expect to be even drier. Rainfall intensity is expected to increase
- Extreme events: an expected increase in the frequency and intensity of extreme events, primarily droughts and floods. Expect extreme events to occur in new locations and a shorter growing season in some regions

Uncertainty

One thing is certain; under climate change uncertainty will increase. When making climate change impact assessments, a 'cascade' of uncertainty arises (e.g. uncertainty with modelling, scenarios and data) making it difficult to make reliable predictions. The impacts predicted need to be considered alongside current

[1] Hot' day or 'Hot' night is defined by the temperature exceeded on 10% of days or nights in the current climate of that region (average)
[2] 'Cold' days or 'Cold' nights are defined as the temperature for the coldest 10% of days or nights (average)

population pressures and existing vulnerabilities - even without anthropogenic climate change, climate variability undermines food security, negatively affects the environment and significantly affects livelihoods. Therefore the most pragmatic approach is to develop the resilience of water and sanitation systems-– managing risks and building their capacity to deal with unpredictable events, prioritising no-regret measures (UNWATER, 2009).

CLIMATE SCENARIOS

To assess the impacts of climate change on Chazanga and Kanyama, the issues resulting from two climate scenarios were reviewed - increasing and decreasing precipitation. Two scenarios were assessed due to the uncertainties predicting future precipitation. However, rainfall intensity (the rate at which rain falls) is expected to increase, so this was included in both scenarios (Table 1). Determining which of the issues may be significant for the settlements was assessed during the field visit to Lusaka.

Table 1: Key issues resulting from climate changes in Kanyama and Chazanga (the appendix summarises the impacts of the key issues on water and sanitation technologies)

	Increase in precipitation, increase in rainfall intensity	Decrease in precipitation, increase in rainfall intensity
Kanyama	**Water Supply** Flooding increases Groundwater recharge increases Increase in extreme rainfall events Run-off increases	**Water Supply** Localised flooding increases/flash floods Increase in extreme rainfall events Run-off increases
	Sanitation Flooding increases; increase in extreme rainfall events Groundwater tables rising	**Sanitation** Localised flooding increases/flash floods; increase in extreme rainfall events
Chazanga	**Water Supply** Increase in extreme rainfall events Run-off increases	**Water Supply** Increase in extreme rainfall events Run-off increases Water availability in shallow wells and boreholes decreases
	Sanitation Flooding increases; increase in extreme rainfall events	**Sanitation** Increase in extreme rainfall events Water availability in shallow wells and boreholes decreases

IMPACT OF CLIMATE CHANGE NOT DIRECTLY RELATED TO WATER AND SANITATION

The following summarizes the main indirect impacts of climate change on Zambia; refer to the climate change briefing (Heath, 2010) for a comprehensive overview:

- **Food insecurity – principally maize**: Increasing temperatures and a shorter growing season will decrease the area suitable for maize production in the North and centre of Zambia by 80%, while maize yields may decrease by 66%. This will increase the price of maize, affecting poorer communities and reducing the number of meals taken. The GDP of Zambia is closely correlated with precipitation due to the importance of rain fed agriculture in the economy, this will decrease if there is less rainfall (Thurlow *et al*., 2009); This will lead to increased migration. The migrations will typically be to urban areas, where the migrants are often more rather than less vulnerable to certain climate-related impacts (DFID 2010). The increased populations in urban area will increase competition over natural resources.
- **Charcoal:** Increasing temperatures and decreasing rainfall will reduce the regeneration rate of *Miombo* woodland, increasing the price and scarcity of charcoal. *Miombo* woodland covers 60% of the land and provides fuel and charcoal for 80% of households (MEWR, 2008, UN-REDD, 2010);
- **Electricity**: A reduction in rainfall will decrease the availability of water for hydroelectric (90% of the electrical supply), leading to power shortages (MTENR, 2007).

Impact of climate change on water resources in Lusaka

Before assessing the vulnerability of the peri-urban areas to the climate change, it is necessary to review how climate change will impact water resources in Lusaka. Lusaka relies on groundwater and water piped from the Kafue River. However, there is very little information publicly available on water resources in Lusaka or even Zambia. Some information is available in the IWRM national plan (MEWR, 2008) which overviews the water resource situation in Zambia. During interviews stakeholders mentioned a water balance has been completed by the Water Board, ZESCO and the Zambezi River Basin authority but this was not available; similarly, the WWF are currently modelling abstractions from the Kafue river. However, there is evidence available that Kafue River's water quality is continuously deteriorating (heightened eutrophic conditions, increased heavy metals and suspended solids, decreased fish catch and objections of taste, (Kambole, 2003)). The impact of the climate changes on water resources are outlined below:

- **Increasing precipitation** will increase the volume of water available from the Kafue River and groundwater; however there will be an increase in localized flooding (resulting from poor drainage). Any increase in intensity of rainfall will intensify flooding and soil erosion in Lusaka
- **Decreasing precipitation** will have a severe impact on groundwater resources in Lusaka. If the water available for abstractions is decreased there will be increased reliance on the Kafue River, which may also have a lower supply due to less rainfall and an increased concentration of contaminants. The predicted rise in temperature will increase evaporation from the river and the volume of water needed for irrigation. Decreasing rainfall will lower the river levels; therefore more water is likely to be retained by the hydroelectric dam at the Itezhi-tezhi (upstream of the abstraction point for Lusaka), further reducing volume of water in the river. This will be exacerbated by the proposed closure of the Nkana Copper mines, which were pumping 500 m^3 a day into the river supplementing the low flow. In addition, the Kafue water works (which treats 50% of Lusaka's water) is old and in need of repair making it more likely to fail to treat river water, which will have less water available for dilution

The sustainability of ground water was assessed qualitatively during the field visit to Lusaka. The stakeholders were asked if the current abstraction was sustainable. The majority believed it was not; the most notable exception was the Acting Deputy Director of Water Affairs and Energy who believed there was sufficient water. Figure 3 outlines the opinions of stakeholders from different organizations. The main reason abstraction was viewed as unsustainable was the lack of regulation; however, a Parliamentary Bill is being proposed requiring the registering of boreholes, which should improve the understanding of how much water is being extracted. Most informants believed there should be more water piped from the Kafue River.

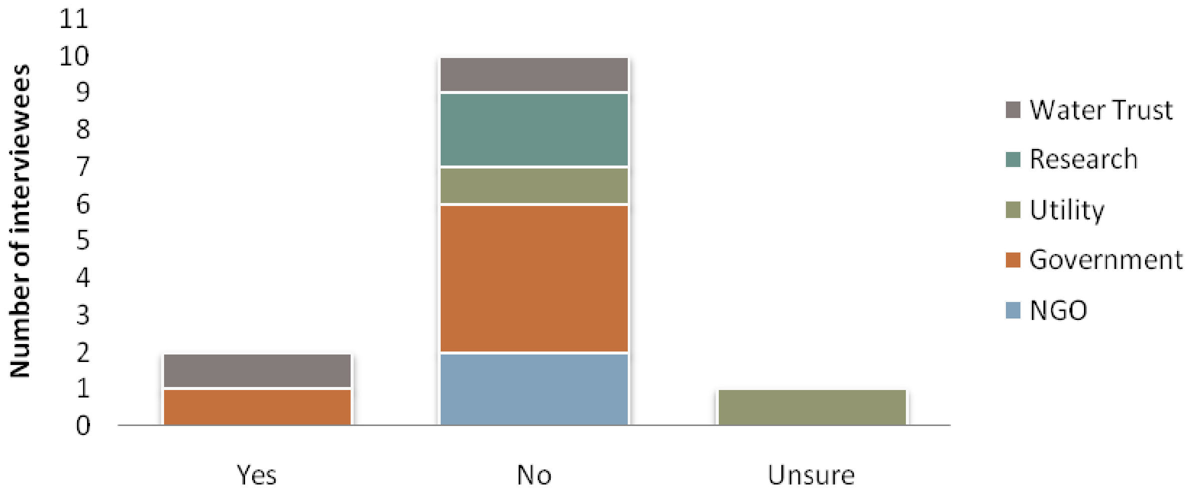

Figure 1 Results of interviewees' response to the question "Is ground water abstraction in Lusaka sustainable?"

Impact of Climate Change on Chazanga

Climate change is likely to exacerbate or reduce existing vulnerabilities rather than create new problems (Figure 2 and 3 overviews the existing vulnerabilities). The following outlines the impact of climate change on water and sanitation in Chazanga.

Increasing Precipitation

An increase in rainfall will have a positive impact upon Chazanga, as it will increase groundwater levels, which will decrease the risk of water shortages, the shallow wells drying up and equipment being over used (shortening its lifetime). Due to the area's topography flooding is unlikely to be a future problem. However, the increase in precipitation will intensify the poor drainage at the kiosks leading to more stagnant water and associated health risks. In addition increases in temperatures will likely reduce crops yields, increasing poverty and migration into the area, which will in turn increase the demand for land and associated pressures on sanitation (lack of space, open defecation, fly tipping of faeces).

Decreasing Precipitation

Decreasing precipitation will exacerbate most of the current environmental problems in Chazanga. The main risk is a lower water table, poor drainage at the kiosks, power shortages and damage to infrastructure; of these a lower water table has the largest number of impacts on Chazanga. Lower water tables cause water shortages, grit to get into the pipes and the drying up of shallow wells. This leads to insufficient water, long queues at the kiosk, an increase in vandalism/illegal connections and an increase in shallow well use (although if these dry up there will be an even greater demand from the kiosks). There will also be public health risks from an increase in inappropriate water saving in the home and potentially lower pressure in the system leading to ingress of contaminants and damage to infrastructure. Decreasing precipitation combined with increasing temperature will decrease the maize yields, the land available for farming and the *Miombo* woodland, increasing the risk of migration and poverty. This will exacerbate the Water Trusts' lack of finance, which undermines operations, limits maintenance, new infrastructure and the expansion of the kiosk network.

Increasing Rainfall Intensity

An increase in rainfall intensity will result in the erosion of boreholes and kiosks leading to the loss of supply and contaminants entering the system. Latrines will be at greater risk of collapse and the erosion of soil around septic tank's absorption field will reduce its efficiency. The increase in intensity of rainfall will also increase the risk of the shallow wells being contaminated.

Impact of climate change on Kanyama

Climate change is likely to exacerbate or reduce existing vulnerabilities rather than create new problems (Figure 4 and 5 overviews the existing vulnerabilities). The following outlines the impact of climate change on water and sanitation in Kanyama.

Increasing Precipitation

In Kanyama increasing precipitation will exacerbate most of the current environmental problems. It will increase the risk of flooding, latrines being submerged and contamination of shallow wells. Kanyama is most at risk to flooding, which causes kiosks and buildings to be filled with water and collapse, contaminates the water supply, affects livelihoods, education, and health and makes standpipes inaccessible. Submerged latrines and contamination of shallow wells are linked and lead to annual outbreaks of cholera and diarrhoea disease. The lack of space (which will intensify due to climate induced migration) and the unplanned nature of Kanyama are putting pressure on the settlement's boundaries (land is being stolen from farmers). This in turn limits the drainage effectiveness, encourages the fly tipping of faeces and limits the options for latrine emptying all of which increase the health risks. In addition groundwater levels are likely to rise, which will exacerbate the problem of collapsing and overflowing latrines and may create pathways for rapid dispersal of contaminants.

Decreasing Precipitation

Decreasing precipitation will have a positive impact on Kanyama, as it will reduce the risk of flooding, but there will still be a sufficient quantity of water available for domestic uses. Less rainfall will lower the water table (currently 2 m below ground level) lowering the risk of groundwater floods. But the increase in intensity will still cause problems for Kanyama and may lead to localised flooding, damage to infrastructure and contamination of the shallow wells. In addition increases in temperatures will likely reduce crop yields, increasing migration into the area. This will increase the demand for land, the construction of poor quality latrines and number of households with no access to safe water.

Increasing Rainfall Intensity

An increase in rainfall intensity will increase the severity of the floods (and the speed of onset) resulting in the erosion of boreholes and kiosks leading to the loss of supply and contaminants entering the system. Latrines are more likely to collapse and erosion of the soil around septic tank's absorption field will reduce its efficiency.

CLIMATE CHANGE AWARENESS

As well as increasing the resilience of water supply and sanitation systems, working with other organizations to build capacity and share knowledge is key for successful adaptations to climate change. Therefore an understanding of the current climate awareness and actions of the different stakeholders is needed. Table 2 gives a rough assessment of this information based on stakeholder interviews.

Table 2: Climate change awareness and actions of organizations in Lusaka

Stakeholder	Awareness	Plans/Actions	No. Interviews
Community	Limited	None	11
Water Trust	Limited	None	12
LWSC	Low	Not assessed in work	2
City Council	Medium	• Disaster management unit, headed by town clerk, looks at flooding and drought	3
Government	Awareness at policy level but little implementation	• Large scale projects with SADC • Incorporating climate change into 6th national development plan • preparing 2nd communication to United Nation Framework Convention on Climate Change UNFCCC • Climate Change Facilitation Unit • Vulnerability Assessment Committee • Reducing Emissions from Deforestation and forest Degradation Initiative	8
Research	High and advocates of Climate change	• Involved in 6 national development plan, trying to mainstream climate change • Research projects (MSc and PhD)	2
NGOs	2 involved in capacity building and awareness raising, 1 had limited knowledge	• Prepared reports on vulnerability • Set up climate change civil sector partnership • Tried to implement carbon capture project (WWF) but there is no national REDD framework so unable to	3

Recommendations

Adapting to climate change requires a combination of technological and structural measures, risk sharing and capacity building to increase the robustness of systems. Coping with climate change does not involve many entirely new processes or techniques. It should, however, be made clear that this is not an argument for 'business as usual'. Existing instruments, methods and measures may need to be introduced at a faster pace, and applied in different locations, at different scales, within different socio-economic context and in new combinations (CAPNET, 2009). Developing water safety plans should be a priority, to reduce the risks to water supply by establishing a framework for managing the risks to drinking water from catchment to consumer (refer to Bantram 2009).

This section reviews the key adaptations for Chazanga and Kanyama Water Trust, Lusaka Water and Sewage Company and Lusaka City Council. The adaptations were determined based on a field visit, a vulnerability assessment and selective literature review – refer to the appendix for further details. Some recommendations will be part of existing maintenance programmes; however, the priority of these actions may need increasing. The adaptations have been divided into three timescales (based on Venton, 2010):

- **Short term:** contingency adaptation for extreme events – e.g. Drought management Flood forecasting, focus on disaster management experience;
- **Medium term:** tactical adaptations regarding climate variability, linked with disaster risk reduction;
- **Long term:** adaptations necessary to respond to a predicted different climate.

The adaptations are then divided into four categories (based on Charles *et al*., 2010):

- **Capital expenditure**, which includes new investments and projects;
- **Operational expenditure**, which includes adaptations that can be made to existing systems;
- **Monitoring**, which includes programmes that can be implemented immediately to support planning decisions, or implemented in the long term to support continuing decisions;
- S**ocioeconomic,** tools such as community education, training and public awareness that can support short and long-term adaptations.

Adaptations in Chazanga

The main impacts of climate change in Chazanga are water shortages and damage, in addition in the future the large growth will increase land pressure and exacerbate the problems associated with the limited latrine emptying options. The main adaptations to each of these issues are outlined below:

- **Water Scarcity**: the principle causes are a lower water table and power shortages. In the short term acquiring a generator will help reduce the problem. In the longer term drilling a new borehole and/or installing a direct line from Lusaka Water and Sewage Company will reduce the vulnerability. Deepening the borehole is an option (as long as the borehole is not at the base of the aquifer), but will require development to alleviate the problem of grit getting in to the borehole; otherwise a lower pumping rate should be used for a longer duration. In addition new boreholes and kiosks are needed to reach the unserved.
- **Damage to Infrastructure:** Protecting the water and sanitation infrastructure requires the stabilisation of the soil around the structures, planting, buffer strips, storm and erosion reduction measures should be implemented
- **Poor Drainage:** increased intensity of rainfall will exacerbate the poor drainage at the kiosks and increase the volume of standing water (increasing the risk from malaria and contamination). Therefore the building standards for soakaways need to be improved: firstly the soil filtration rate should be tested to determine the minimum size, the sides of the soak away should be checked for silt and the depth may need to be increased (refer to WHO, 1996, 3.9)

Adaptations for Chazanga Water Trust

Immediate/ Short term (0 – 6 months)

Capital Expenditure

- Buy generator for new borehole

Operation Expenditure

- Pipe maintenance programme to reduce leaks
- Adapt maintenance programme to identify breakages (refer to EPD 2007 and DOH 2008)
- Restrict water supplies during droughts
- Ensure high levels of maintenance on kiosks to avoid unnecessary wastage – ensure taps, valves and meter all working
- Ensure functioning water meters in all homes and on all kiosks

Monitoring

- Monitor the impact of droughts on water levels in the shallow wells
- Undertaken sanitary and water use surveys (refer to WHO 1996 2.1)
- Concentrate water quality monitoring of shallow wells during periods of droughts and after heavy rains
- Monitor the microbial quality of water at kiosks

Social Economic

- Implement education programme to improve efficiency of use
- Promote and raise awareness of the importance of hygiene
- Mount ropes and buckets at shallow wells and protect wells from runoff
- Raise awareness of the risks of siting latrines close to shallow wells
- Identify the most at risk shallow wells and develop communication procedures to notify the community which are not safe
- Educate communities about reliable water sources: how to select them, what makes them reliable
- Raise awareness among the community about the damage that erosion can cause to infrastructure, and the potential effect on the water supply system

Medium Term (6 Months – 1 year)

Capital Expenditure

- Use durable materials when constructing kiosks – use builders sand and ensure adequate cement used
- Ensure well heads are properly designed to prevent erosion damage that may increase infiltration (refer to WHO, 2003)
- Use compaction of soils and planting around infrastructure to increase durability of structures and maintain conditions which mitigate erosion, e.g. planting schemes, compaction of soils and plants in buffer strips
- Expand the kiosk network, prioritising unserved areas
- Encourage the development of double vault ECOSAN latrines to deal with lack of space expected with growth

Operation Expenditure

- Prepare Water Safety Plan to manage risks to water supply (guidelines in Bantram, 2009)
- Replace old pipes
- Reduce illegal connections and leakage
- Maintain positive pressure in pipes or close kiosk before supply runs out (refer to Franceys, 2010)
- Repair erosion damage and sod (turf) or seed areas as necessary to provide turf grass cover

Monitoring

- Monitor pipes for blockages and breaks
- Septic tank system inspections of pit (check no build up of silt) and absorbtion field (refer to WHO, 2003)
- Regularly check abandoned borehole is properly sealed to protect groundwater quality

al Economic

- Education and awareness raising of lower-water use latrine options (refer to Scott 2005)
- Encourage reuse of water in community

Long Term (1 year^{+})

- Consider deepening screen on old boreholes. Install relief boreholes that can be uncapped for easy use in dry periods to supplement existing wells
- Install pressure release valves
- Investigate direct connection from LWSC
- Investigate and if possible implement alternative and supplementary water sources and water harvesting methods
- Examine lower-water use approaches (plastic seals rather than water seals) and slabs that are easier to clean and use less water (refer to Scott 2005)
- Consider low-flush toilets. If no water available, septic tanks will not be a viable option. Investigate other systems for management of human excreta such as ECONSAN
- Investigate methods for the artificial recharge of groundwater/Investigate catchment management practices to promote infiltration (refer to GBR, 2009, WHO 1996, 2.5)
- Construct public toilets in wetland places where it is expensive to construct private toilets for individual homes
- Construct kiosks with shelters to protect vendor, protect equipment and allow for other income generating activities

Adaptations in Kanyama

The main impacts of climate change in Kanyama are an increase in flooding due to poor drainage and the contamination of water due to overflowing latrines. In addition expanding the kiosk network needs to be prioritised to provide safe water to the community particularly during the floods. The main adaptation's to each of these issues is outlined below.

- **Flooding:** The main priority for Kanyama needs to be addressing the localised flooding which devastates the area. The council and various NGOs are improving the drainage, but this work needs to be expanded as climate change will increase the severity of the flooding. The key actions are clearing the drainage ditches of rubbish and the rock, develop and expand the drains which run into the main drains and moving houses which block the drains
- **Overflowing latrines:** Improving the drainage will reduce the flooding in Kanyama, however even with improved drainage there is likely to be localised flooding due to blocked drains or rising ground water, so the latrines will still overflow. There needs to be assistance with emptying latrines (current and those which have collapsed), and ensuring new latrines which are built high enough to avoid sewage overflowing. Encouraging regular emptying will also address the limited land issues. As flooding is still an issue ECOSAN should be reviewed as there is little market for the sewage and the latrines are not well adapted to the floods, in the longer term, a decentralised sewage system is the most sustainable options as long as it is well maintained
- **Kiosk network:** The network needs to be expanded to ensure every household has access to safe water during floods. This will require the sinking of additional boreholes and further investment and support to the water trust. It is also worth considering adjusting the design of the kiosks to the shelter structure as this will improve the lifetime of the valves, taps and enable the vendor to sell products and have shelter

Kanyama Water Trust

Immediate/ Short term (0 – 6 Months)

Capital Expenditure

- For deep boreholes ensure the casing extends below the level of shallow aquifers. Extend lining above flooding level

Operation Expenditure

- Regular programme of leak detection and repairs (refer to EPD 2007, WHO 2001 and DOH 2008)
- Flush out pipes and clean standpipes after floods (refer to WHO, 1996 2.27)
- Shock chlorinate borehole water after the floods have subsided (refer to WHO, 2005 & WHO 2.25)
- Develop response plan after flooding to assess damage to standpipes and to inform future improvements (refer to Reed 2006)
- Adapt water treatment to respond to changing water to ensure that water quality is not compromised during or after floods

Monitoring

- Monitor the response of groundwater levels and quality to increasing rainfall
- Monitor water quality and adapt treatment processes Sanitary inspection of standpipes (refer to WHO, 1996 2.27)
- Testing of shallow wells, raise awareness of high risk wells in community

Social Economic

- Advise the community to avoid using contaminated springs for drinking during and after floods, until quality has been verified
- Develop communication procedures to notify the community when the water is safe

- Raise awareness about potential health issues associated with sewage and dangers of emptying pits for floods to wash away
- Raise awareness of the dangers of latrines close to shallow wells (refer to Cave and Kolsky 1999)

Medium term (6 Months – 1 year)

Capital Expenditure

- Where possible, implement land management activities to increase infiltration of water and reduce severity of floods, e.g. terracing, reforestation (refer to BGT, 2009 & WHO, 1996 2.5)
- Improve borehole lining to prevent ingress of water from soil and shallow groundwater, ensure that borehole are sealed to several metres below the water table
- Site new boreholes well away from latrines and other sources of groundwater pollution
- Build bunds (banks, dykes or levees) to divert floods away from borehole, or raise the well head
- Ensure that wellheads are properly designed to prevent erosion damage that may increase infiltration. Use compaction of soils and planting around infrastructure to increase durability of structures
- Aim to site pipes in areas at low risk to flooding. Relocate water pipes away from open sewers and drainage channels
- Construct standpipes from durable materials (including mesh foundation) to reduce damage during floods , avoid using local material, use proper building sand
- Place kiosks on elevated platforms to allow access during floods
- Minimize erosion with planting schemes, buffer strips and storm water management
- Construct new kiosks and storage tanks to expand network to unserved areas

Operation Expenditure

- Prepare Water Safety Plan to manage risks to water supply (guidelines in Bantram, 2009)
- Repair rendering of borehole wall when necessary (refer to WHO, 2003)
- Maintain well head protection areas (refer to WHO, 2003)
- Investigate increasing protection zones around boreholes (acquire land), minimum of 15 m to latrine, raise awareness in community, empty near latrines and close (refer to Cave and Kolsky, 1999)
- Protect pipes under road: signs to alert vehicles, deepen pipes
- Introduce a pipe maintenance programme to reduce leakage and potential for ingress (repeated check)
- Rehabilitation to improve pressure in system (refer to Franceys, 2010)
- Flush out flooded pipe network after waters have receded to remove sediments
- Pipe maintenance programme to fix leaks in pipes
- Reduce illegal connections and leakage
- Ensure functioning water meters in all homes and on all kiosks
- Maintain conditions which mitigate erosion, e.g. compaction of soils and plants in buffer strips Improve soakaways at kiosks

Monitoring

- Monitor microbial quality of water after the well or borehole has been renovated
- Develop and implement reporting mechanism when areas above pipes are flooded. Review risks and need for refurbishment or replacement

Social Economic

- Raise awareness about potential health issues associated with sewage (refer to Curtis 2005, Appleton and Sijbensema, 2005)
- Community education on latrines on the need to empty regularly, post flood rehabilitation to remove silt, to plant shrubs around latrines (reduce pit erosion), build smaller pits (less risk of collapse and less sewage to contaminate) and the importance of regular maintenance (limit vulnerability to collapse) (refer to Scott 2005)
- Raise awareness of need to the restart composting in ECOSAN latrines following flooding to redress moisture balance (refer to Smet and Sugdon 2006)
- Hygiene education at kiosks, train to keep area clean, avoid standing water and check containers

Long term (1 year+)

- Develop back-up sources, such as linkages to other water sources or community water supply systems
- Provision of alternative water sources during inundation or household treatment (who sheet)
- Construct kiosks with shelters to protect vendor, protect equipment and allow for other income generating activities
- Review the risks and benefits of removing the standpipe if it is located in an area at high risk of flooding
- Maintain hygiene education in community sewage (refer to Curtis 2005, Appleton and Sijbensema, 2005)
- Construct public toilets in slum areas in wetland places where it is expensive to construct private toilets for individual homes

Sewers

- Build decentralised sewers (refer to Gate 2001)
- Local decentralized treatment will reduce pumping costs and enable local responsive management when system is vulnerable to damage
- Low-cost sewers can be more easily maintained or replaced when damaged, but are more vulnerable to erosion. Have spare parts available
- Ensure that sewers are gravity flow wherever possible. Low-cost and shallow sewers have much lower pumping requirements
- Do not locate sewers in soils which are regularly waterlogged. Low-cost and shallow sewers may be less susceptible and above groundwater levels
- Site sewers pipe away from drainage channel. Compaction of soil and planting above sewers, under paved roads etc. Clean sewers regularly. Clean drains regularly especially just before wet season
- Monitor silt levels, blockages, cross connections, in drains and sewers

Other Stakeholders

The two other main stakeholders are Lusaka Water and Sewage Company (LWSC) and the Lusaka City Council. LWSC are responsible to NWASCO (regulator) for ensuring water and sanitation services meet the legal requirements. Their principle role is providing technical support (both staffing and equipment) and working with the peri-urban unit to secure new funding from the Devolution Trust Fund. The city council's role is providing local services in the peri-urban area areas: drainage, roads, waste collection, public health and planning. The city council also work with the Ward Development Committees (elected representatives from the community) who identify key areas of concern in the settlements. The urban poor are vulnerable to hazards induced by climate variability; however, they also have a certain level of built-in-resilience (preventative, impact minimizing and economic strategies, asset accumulations, and development of social support networks) which must be recognized and which can be better supported by planning initiatives from the City Council (Allen *et al*., 2010). A central role of the council should be addressing the issues of adaptation within their existing programmes and projects as an integral part of development plans rather than creating separate adaptation plans. The following identifies how LWSC and the city council should adapt to climate change and support the peri-urban areas. The adaptations for LWSC are split into the short, medium and long term, while those for the council are further dived into capital, operation, monitoring, policy changes and social economic adaptations.

Lusaka Water and Sewage Company

Short term (0 – 6 months)

- Install pressure release valves for both settlements
- Assist in improving well head protection areas and well head inspection (refer to WHO, 2003)
- Responsibility for ensuring water quality meets NWSACO standards

Medium term (6 months – 1 year)

- Raise finances for new infrastructure from DTF in Chazanga and Kanyama
- Assist in deepening screen in borehole in Chazanga
- Investigate link between groundwater recharge and rainfall intensity in Chazanga
- Construct new storage tanks for both settlements
- Rehabilitation of pipe network to improve pressure in systems(new storage tanks, pressure release vales)(refer to Franceys, 2010)
- Establish/expand peri-urban unit to provide technical and administrative assistance during flooding
- Assist expanding the kiosk network
- Determine the degree of vulnerability through investigating linkages between rainfall and groundwater, e.g. residence times
- Raise awareness among water resource managers and water engineers about the potential for lateral transport of pathogens and subsequent contamination of water

Long term (1 year+)

- Develop back up supplies for Chazanga, install main line connection for Chazanga
- Investigate methods for the artificial recharge of groundwater/Investigate catchment management practices to promote infiltration (refer to BGR, 2009 &WHO, 1996 2.5)
- Assist deepening boreholes. Install relief wells that can be uncapped for easy use in dry periods to supplement existing wells

Municipality – Lusaka City Council

Short term (0 – 6 months)

Operation Expenditure

- Repair plinths and clear ditches of rubbish and silt

Monitoring

- Identify most at risk shallow wells and make community aware which are high risk

Social Economic

- Develop communication procedures to communicate when water is safe
- Hygiene education at shallow wells, advise the mounting of rope and bucket and protecting shallow wells from runoff
- Raise awareness about potential contamination of drinking-water supply, the risk during floods, health issues associated with sewage and the risks of emptying the latrines for the flood to disperse
- Dissemination of public health messages with advice about dealing with the issues, including household treatment and boil water notices where appropriate
- Raise awareness on risk of latrines close to shallow wells and the need for regular emptying
- Raise awareness about the dangers of unstable pit latrines

Medium term (6 months – 1 year)

Capital Expenditure

- Implement land management activities to reduce severity of floods, e.g. terracing, adequate drainage, reforestation, retention basins
- Increase size of ditch and plant trees on side of ditches
- Buy/move houses blocking drains
- Ensuring that local drains feeds effectively into the main drainage channel and construct new feeders if necessary
- Have a permanent workforce to maintain and clean the drainage system

Operation Expenditure

- Proper garbage and solid waste disposal together with increased awareness (repair garbage truck)
- Enforce no dumping of latrine matter, improved emptying options, make community aware of risks

- Regulate better quality construction of latrines/improve standards (refer to Scott, 2005)
- Subsidise tanker/provider free removal of waste

Monitoring

- Monitoring and regulation systems should focus on emptying and faecal sludge management as well as construction of latrines
- Mapping most vulnerable sites in need of intervention

Social Economic

- Raise awareness among the community about the damage that erosion can cause to infrastructure, and the potential effect on the water supply system
- Move away from composting - not appropriate for Kanyama in the longer term
- Site latrines at least 15 m away from drainage channel (Cave and Kolsky, 1999)
- Encourage users/enforce standards for pit latrine: superstructure at the same level as the houses; build round pits instead of square (increase stability); regular emptying and post-flood rehabilitation to remove silt; plant shrubs around latrines (reduce pit erosion); build smaller
- Advocate the importance of regular maintenance, proper compaction of soil around the latrine and presence of adequate base and earth filling to protect pits (refer to WHO, 2003)
- Raise awareness of need to restart composting following flooding event to redress moisture balance
- Raise standards for septic tanks: use durable materials in construction; design to prevent ingress of silt; secure pit to ground (prevent floating on flood) and install non return vales (shut during floods)
- Raise awareness of monitoring and maintenance requirements for septic tanks: empty tank post flood; dangers of waterlogged soakways; need to plant grasses and shrubs in the absorption area, and around the septic tanks (reduce erosion); check the vegetation over the septic tank and soil absorption field after flooding; build bunds (banks, dykes or levees); awareness of signs of failure of an absorption field, and how to fix it or construct a new one and the need to empty (refer to WHO, 2003)
- Ensure tank full of water during flood to prevent damage to the infrastructure. However, lids need to be properly fitted and secured to prevent sewage overflow

- Long term (1 year^{+})

Capital Expenditure

- Invest in market for composted sewage in Chazanga (refer to Scott and Read 2006)
- Construct a deeper and wider main drain in Kanyama to accommodate the increased flooding water
- Use sustainable urban drainage systems and separate sewers in Kanyama. Encourage decentralized systems

Policy

- Facilitate security of tenure to allow residents to stay longer and develop stronger ties to the community and better networks
- Tighter planning and regulation of land tenure, working with farmers
- Support saving schemes of the urban poor facilitating access to financial institutions
- Adopting modifications practiced at the household level into housing, land use and infrastructure municipal plans and procedures
- Advocate ECOSAN latrines in Chazanga, set up with marketing, hygiene awareness on reuse and not putting rubbish in latrines
- Developing opportunities for communication and sharing experiences among local government and grassroots organizations about how to build better resistant housing and infrastructure
- Developing building codes that specify measures like increasing plinth height or window locations, allow families to share infrastructure; increase building standards for washrooms

Social Economic

- Ensure that users know they should keep moisture out of ECOSAN latrines after flooding
- Support use of alternative building materials and appropriate technology look into quality of materials, raise awareness of which are not suitable (refer to ITDG, 2007)

Response to Recommendations

A response to the following questions will be included from Chazanga, Kanyama, LWSC and Lusaka City Council:

1. How will [stakeholder] respond to the climate proofing recommendations?
    a. How will the adaptations be implemented?
    b. How do they impact long term plans?
2. What additional information do you require to apply the adaptations?

Further Information

Climate modelling and climate change adaptation are both areas of continuing research. It is important to be aware of the ongoing work being undertaken which will inform future investments and adaptations. Table 5 illustrates that although climate change is recognised at the policy level, there is little work being implemented. As policy filters down it will have a greater impact on resource management and it is important to stay aware of changes to policy.

Current Research

The following lists the key research currently being undertaken in Lusaka, detailing the principle organisation, and the purpose of the work.

Principle Resources

- **Second National Communication to the United Nations Framework Convention on Climate Change.** A draft being prepared by the Climate Change Facilitation Unit (established by Ministry of Tourism, Environment and Natural Resources). The report includes a review of the major activities and an inventory of greenhouse gas emissions; assessment of potential impacts of climate change on the most vulnerable sectors; analysis of potential measures to abate increase of greenhouse gases; and capacity development for reporting on climate change. The project is supported by UNDP and the University of Zambia (www.ccfu.org.zm/)

Secondary Resources

- **United Nations Environment Programme** have produced a vulnerability assessment and are working on an assessment of the climate change information gaps (www.undp.org.zm)
- **Integrated Water Resources Management and Water Efficiency planning process** is being implemented by the Ministry of Energy & Water Development (www.mewd.gov.zm)

- **Zambia Water Partnership** is a partnership comprising of stakeholders in the water sector and interested organisations. It has a mandate to promote the implementation of Integrated and sustainable Water Resources Management in Zambia. ZWP is currently hosted by the School of Mines, University of Zambia with Dr. Imasiku A. Nyambe as the coordinator (www.zwp.org.zm/index.html)
- **Zambia National Vulnerability Assessment Committee** part of the Disaster management Unit which is a special unit under the Office of the Vice-President of Zambia. They prepare assessments of vulnerability in Zambia (www.dmmu-ovp.gov.zm/)
- **WWF Zambia**. Trying to implement a carbon sequestration project, modelling the Kafue River flows/abstractions and involved in climate change advocacy

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Appendix

Table 3 Overview of interviews undertaken in Lusaka

Organisation	Number of Interviews
City Council	**3**
• Housing and Social Services	1
• Public Health	2
Community	**11**
• Chazanga	6
• Kanyama	4
• Community - Focus Group	1
Water Trust	**12**
• Chazanga	5
• Kanyama	7
Government	**8**
• Devolution Trust Fund	1
• Environment Council	1
• Ministry of Energy and Water Resources	1
• Ministry of Local Government and Housing	2
• Ministry of Tourism, Environment and Resources	2
• National Water Supply and Sanitation Council	1
LWSC	**2**
• LWSC	1
• Zulu Burrow	1
NGO	**3**
• CARE	1
• United Nations Environment Programme	1
• WWF	1
Research	**2**
• National Institute for Scientific and Industrial Research	1
• University of Zambia	1
Total	**41**

VULNERABILITY ASSESSMENT

Understanding the existing vulnerabilities is central to assessing the impacts of climate change. Figures 2 - 5 outline the environmental vulnerabilities and problems with the water supply systems in the settlements and impact of the climate scenarios predicted for Lusaka. There are two assessments for each settlement, one assessing the impacts of increasing precipitation, the other decreasing precipitation, both include increasing rainfall intensity. The factors directly impacted are highlighted red and subsequent impacts are shown in pink – the darker the colour, the greater the likelihood that the problem will be affected by climate change. The figures are as follows:

- Figure 2: Impact of increasing rainfall and increasing intensity on existing vulnerabilities in Chazanga
- Figure 3: Impact of decreasing rainfall and increasing intensity on existing vulnerabilities in Chazanga
- Figure 4: Impact of increasing rainfall and increasing intensity on existing vulnerabilities in Kanyama
- Figure 5: Impact of decreasing rainfall and increasing intensity on existing vulnerabilities in Kanyama

Figure 2 Impact of increasing precipitation and rainfall intensity on existing vulnerabilities in Chazanga (red indicates direct impact of climate change, green no direct affect)

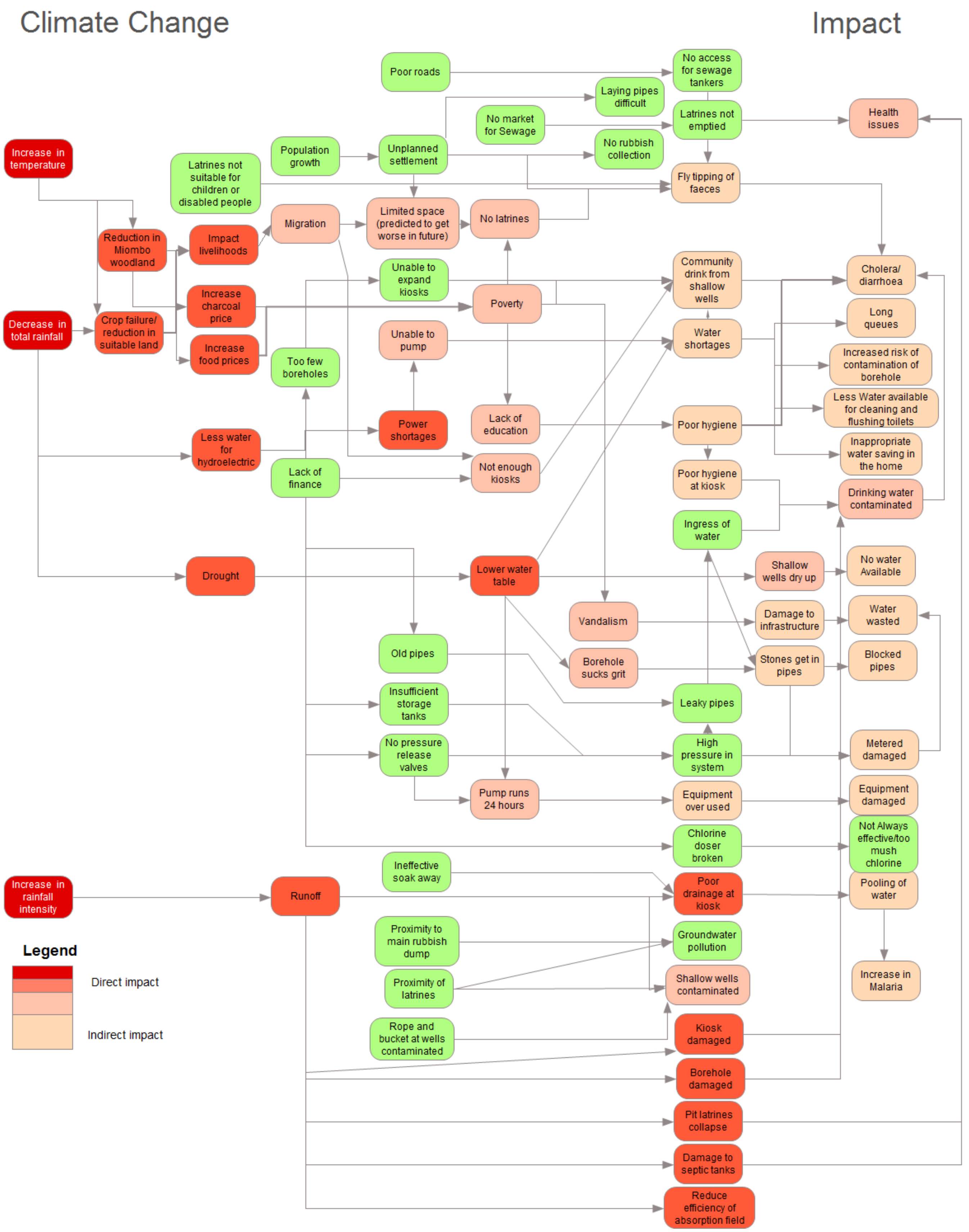


Figure 3 Impact of decreasing precipitation and rainfall intensity on existing vulnerabilities in Chazanga (red indicates direct impact of climate change, green no direct affect)

Figure 4: Impact of decreasing precipitation and rainfall intensity on existing vulnerabilities in Kanyama (red indicates direct impact of climate change, green no direct affect)

Figure 5: Impact of increasing precipitation and rainfall intensity on existing vulnerabilities in Kanyama (red indicates direct impact of climate change, green no direct affect

LITERATURE REVIEW

In addition to identifying the impacts of climate change on the existing vulnerabilities and problems in Chazanga and Kanyama the literature was reviewed to assess the impact of climate change on water and sanitation technologies. The following tables overview how the technologies (current and planned) are vulnerable to the key issues (outlined in Table 1) and the resulting impacts. The tables are based on observations during the field visit and literature, which assesses the impact of climate change on technology – principally a review completed by the WHO and DFID in 2010 (Charles *et al*., 2010).

Impact of Climate Change on Technology in Chazanga

Community-managed drinking water systems (direct connections)

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Water availability decreases	Insufficient water for demand, or increased seasonality of water	Water shortages and potential for water rationing. Public health risk from inappropriate water saving in the home. Low pressure in system may allow ingress of contamination into the water distribution network. Intermittent water supplies and pressure changes in the distribution network lead to damage of the infrastructure	Restrict water supplies and switch pipes off. Increase water storage capacity to provide supply over extended dry periods Investigate alternative water sources and water harvesting methods	Pipe maintenance programme to reduce leaks. Prioritize allocation for domestic use.	Monitor for microbial quality of water.	Educate communities about reliable water sources: how to select them, what makes them reliable, etc.
Run-off increases	No threat					

Kiosk/ Standpipe

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Water availability decreases	Addressed in community managed supply					
Run-off increases	Erosion damaging standpipe.	Destruction of the standpipe and loss of service. Public health risk from contaminants entering the standpipe	Land management – minimize erosion with planting schemes, buffer strips and storm water management. Use durable materials in construction	Maintain conditions which mitigate erosion, e.g. compaction of soils and plants in buffer strips.	Sanitary survey.	Raise awareness among the community about the damage that erosion can cause to infrastructure, and the potential effect on the water supply system

Borehole

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Water availability decreases	Insufficient water for demand	Water shortages and potential for water rationing. Public health risk from inappropriate water saving in the home	Investigate alternative and supplementary water sources and water harvesting methods, such as rainwater collection and water reuse. Prioritize water use for drinking. Investigate methods for the artificial recharge of groundwater Investigate catchment management practices to promote infiltration. Consider deepening the wells and boreholes	Ensure high levels of maintenance on wells to avoid unnecessary losses of water at the point of use	Monitor water use at well for user pays scheme, and assist in demand management. Monitor the ability of wells to cope with current droughts	Implement education programme to reduce water demand. Promote the importance of hygiene

	Increased use of viable wells causes increased wear and tear, and increased water demand	Damage to well or borehole increases the risk of contamination entering water source. Public health risk from consumption of the water	Determine the degree of vulnerability through investigating linkages between climate and groundwater, e.g. residence times	Ensure high levels of maintenance on in demand wells	Sanitary survey. Monitor the ability of wells to cope with current droughts	
	Less water available for hygiene and cleaning	Public health risk from inappropriate water saving in the home	Research cleaning and hygiene methods that have low-water usage		Water use surveys	Raise awareness of the importance of hygiene
	Groundwater levels dropping, especially during a dry period or season	Water shortages and potential for water rationing. Public health risk from inappropriate water saving in the home. Increased risk of contamination of the water at the end of the drought	If supply from the well is already variable, consider that the current well may need to be extended or new deeper wells may need to be installed. Install relief wells that can be uncapped for easy use in dry periods to supplement existing wells	Determine the degree of vulnerability	Concentrate water quality monitoring during periods of high risk at the end of the droughts	
Run-off increases	Erosion	Permanent loss of borehole or well. Damage to the structure of the borehole or well, leading to a temporary loss of supply. Public health risk from contaminants entering the standpipe	Ensure that well heads are properly designed to prevent erosion damage that may increase infiltration. Use compaction of soils and planting around infrastructure to increase durability of structures	Maintain conditions which mitigate erosion e.g. compaction of soils and plants in buffer strips.	Monitor microbial quality of water after the well or borehole has been renovated	Raise awareness among the community about the damage that erosion can cause to wells and boreholes. Develop communication procedures to notify the community when the water is safe

SEPTIC TANKS

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Increase in extreme rainfall events; run-off increases	Erosion of soil around the tank and absorption field	Damage to infrastructure. Reduced efficacy of the absorption field	Planting of grasses and shrubs on the absorption area, and around the tank, to reduce erosion. Repair erosion damage and sod or reseed areas as necessary to provide turf grass cover. Build bunds (banks, dykes or levees) to divert flow away from system	Check the vegetation over the septic tank and soil absorption field after flooding.		
Water availability decreases	Less water available for flushing and cleaning	Toilet and discharge pipe becomes dirty or blocked	Examine lower-water use approaches (plastic seals rather than water seals, for example) and slabs that are easier to clean. Increase attention to construction quality and setting out of sewers. More rodding eyes. Steeper falls. Consider low-flush toilets. If no water available, septic tanks will not be a viable option. Investigate other systems for management of human excreta	Consider feasibility of households doing more regular cleaning, rodding etc. Improve solid waste management, especially for fat solids	Septic tank system inspections	Education and awareness of lower-water use latrine options
	Increased distance to groundwater tables	Reduced risk of groundwater pollution	Septic tanks become more viable option			
	Changing moisture levels in soils	Movement and infrastructure damage	Design for movement.	Adapt maintenance programme to identify breakages	Monitor performance for blockages and breaks	

Improved pit latrines

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Increase in extreme rainfall events; run-off increases	Erosion	Collapse of latrine	Site latrine away from drainage channel. Use durable materials in construction to protect pit covers. Proper compaction of soil around the latrine and presence of adequate base and earth filling to protect pits, pit covers and slabs. Install robust upper foundations, collar and footing to protect from erosion and flooding	Regular maintenance essential to limit vulnerability to collapse		Hygiene promotion. Education on regular maintenance requirements
Water availability decreases	Increased distance to GW tables	Reduced risk of groundwater pollution	Pit latrines become more viable option			

Planned: Composting/dry latrines

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Increase in extreme rainfall events; run-off increases	Erosion	Same as improved Pit Latrines				
Water availability decreases	No issues					

IMPACT OF CLIMATE CHANGE ON TECHNOLOGY IN KANYAMA

COMMUNITY-MANAGED DRINKING WATER SYSTEMS (DIRECT CONNECTIONS)

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Flooding increases	Increased flooding reduces the availability of safe water resources	Flooding events increase the level of chemical and microbiological contamination in water sources, increasing the risk to public health. Increased suspended sediment loads carried by flood waters may exceed the treatment capacity of any small scale water treatment system that has been added to the supply	Adopt higher design standards for infrastructure Where possible, implement land management activities to increase infiltration of water and reduce severity of floods, e.g. terracing, reforestation	Establish centralized support unit to provide technical and administrative assistance in the event of flooding	Enhanced inspection of infrastructure	Raise awareness among the community of the risk of contamination during floods and reduction in drinking water availability. Dissemination of public health messages with advice about dealing with the issues, including household treatment and boil water notices where appropriate
	Groundwater quality deterioration during floods	Floodwaters contaminate shallow and deep groundwater sources through damaged or disused boreholes Shallow groundwater may also be affected by infiltration of floodwater through soil layers. Risk to public health from consuming the water	Improve source protection Relocate groundwater source where possible	Impose well head protection areas and well head inspection. Shock chlorination after flood	Sanitary inspection. Intensify water quality monitoring during flood	Develop communication procedures for when water is safe. Raise awareness about risks from water quality changes during flooding and the need for household water treatment
	Entry of contaminated flood water into water supply pipes	Widespread contamination of the water supply system. Risk to public health from consuming the water	Aim to site pipes in area of low risk of flooding. Relocate water pipes away from open sewers and drainage channels	Introduce a pipe maintenance programme to reduce leakage and potential for ingress, possibly with the aid of a central support system. Rehabilitation to improve hydrostatic pressure. Flush out flooded pipe network after waters have receded to remove sediments. Shock chlorination	Sanitary inspection. Develop and implement reporting mechanism when areas above pipes are flooded. Review risks and need for refurbishment or replacement	Issue boil water notices where appropriate. Develop communication procedures for when water is safe
	Contamination of drinking-water in supply affecting whole community	Severe risk to public health from consuming the water	Develop back-up sources, such as linkages to other water sources or community water supply systems. Develop emergency backup supplies	Regular programme of leak detection and repair	Sanitary inspection	Issue boil water notices where appropriate. Develop communication procedures for when water is safe
Groundwater recharge increases	Potential deterioration in the quality of groundwater sources as a result of more	Rising groundwater levels flood sanitation systems, creating pathways for the potentially rapid dispersal of contaminants into groundwater. Rising water level mobilizes microbial and chemical contaminants. Ingress of	Investigate increasing protection zones around wells, to reduce contamination sources. Adapt water treatment to respond to changing water quality. Develop, implement and update water safety plans. Investigate the benefits of placing increased reliance on	Maintain positive pressure in pipes wherever possible. Pipe maintenance programme to fix leaks in pipes	Design and implement a monitoring programme for groundwater sources based on	Raise awareness among the community of the risk of contamination from rising. Dissemination of public health messages with advice about dealing with the issues, including

	rapid transport of water in subsurface, and potential compromising of sanitation systems	groundwater into treated water supply, potentially contaminating water. Significant public health risk from consuming the water	groundwater systems in areas of rising groundwater, provided appropriate treatment can be added. Increase the depth of well intakes, where possible. Move towards continuous positive pressure in system		groundwater level. Monitor the response of groundwater levels and quality to increasing rainfall, to identify vulnerability. Sanitary inspection	the need for household treatment and boil water notices where appropriate.
	Increase vulnerability of flooding	See flooding				
Increase in extreme rainfall events	Water quality, particularly at shallow depths, may deteriorate Increased lateral flow in soils may spread contamination.	Public health risk from contaminants entering the water distribution system.	Consider constructing deeper wells.	Ensure that wells are sealed to several metres below the water table	Monitor water quality and adapt treatment processes to ensure that water quality is not compromised.	Raise awareness among water resource managers and water engineers about the potential for lateral transport of pathogens and subsequent contamination of water.
Run-off increases	No threat					

Kiosk/ Standpipe

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Flooding increases	Standpipes inundated with contaminated floodwater.	Standpipes become inaccessible or are damaged by the floodwater. Quality of the water at the standpipe deteriorates and there is potential for more widespread contamination of the distribution system.	Place on elevated platform to allow access during floods. Construct standpipes from durable materials to reduce damage during floods. Review the risks and benefits of removing the standpipe if it is located in an area at high risk of flooding.	Adopt a standpipe maintenance programme to reduce potential for ingress (e.g. chambers are sealed). Develop response plan after flooding to assess damage to standpipes and to inform future improvement. Flush out pipes and clean standpipes after floods.	Sanitary inspection of standpipe. Increase water quality monitoring after floods have receded.	Issue boil water notices where appropriate. Develop communication procedures for when water is safe.
GW recharge increases	See community managed piped supply					
Increase in extreme rainfall	See community managed piped supply					
Run-off increases	Erosion damaging standpipe.	Destruction of the standpipe and loss of service. Public health risk from contaminants entering the standpipe.	Land management – minimize erosion with planting schemes, buffer strips and storm water management. Use durable materials in construction	Maintain conditions which mitigate erosion, e.g. compaction of soils and plants in buffer strips.	Sanitary survey.	Raise awareness among the community about the damage that erosion can cause to infrastructure, and the potential effect on the water supply system.

Borehole

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Flooding increases	Increased contamination of groundwater and lateral flow in soil	Floodwaters introduce contamination into the groundwater by infiltration though the soil, by damaged or disused bore holes or dug wells. Lateral flow increases, transporting contaminants below the surface. Significant public health risks from consuming the water	Site well away from latrines and other sources of groundwater pollution	Repair rendering of well wall when necessary	Sanitary inspection. Monitor the response of groundwater levels and quality to flooding, to identify vulnerability	Prevent latrines being constructed nearby
	Well is inundated	Widespread contamination of the aquifer, causing long term problems with the quality of water in the well. Significant public health risks from consuming the water	Build bunds (banks, dykes or levees) to divert flow, or raise the well head. Site on embankments. For deep wells, ensure the casing extends below the level of shallow aquifers. Extend lining above ground. Convert dug wells to hand pumped tubewells with sanitary completion. Improve well lining to prevent ingress of water from soil and shallow groundwater, where appropriate. Implement land management activities to reduce severity of floods, e.g. terracing, adequate drainage, reforestation, retention basins	Repair and clear ditches. Increase size of ditch. Repair plinth. Shock chlorinate well water after the floods have subsided. Provision of alternative water sources during inundation or household treatment	Sanitary inspection. Increase water quality monitoring. Monitor conductivity if in coastal or estuarine areas	Issue boil water notices where appropriate. Develop communication procedures for when water is safe
Groundwater recharge increases	Potential deterioration in the quality of groundwater sources as a result of more rapid transport of water in subsurface, and potential compromising of sanitation systems	Significant risk to the health of consumers. Increase in groundwater level could also lead to a reduction in the vulnerability of protected wells and provide a more sustainable water supply than alternative water supply options	Investigate increasing protection zones around wells, to reduce contamination sources. Adapt water treatment to respond to changing water quality. Set intakes at greater depth or modify pumping regimes, where feasible. In the event of a decrease in the vulnerability of protected wells, an increase in the reliance on groundwater sources should be considered	Establish centralized support unit to provide technical and administrative assistance. Act upon sanitary risk inspections	Design and implement a monitoring programme for groundwater sources based on groundwater level. Monitor the response of groundwater levels and quality to increasing rainfall, to identify vulnerability Sanitary inspection	Prevent latrines being constructed nearby. Raise awareness among users of the wells about risks from water quality changes during flooding and the need for household water treatment. Issue boil water notices where appropriate. Develop communication procedures for when water is safe
Increase in extreme rainfall events	See Flooding					
	Groundwater quality, particularly at shallow depths may deteriorate. Increased lateral flow in soils may also spread	Quality of the water from the spring deteriorates. Water quality changes may be long term if the aquifer becomes contaminated	Investigate alternative sources, if appropriate and possible	Properly seal abandoned wells to protect groundwater quality. Maintain well head or spring head protection	Water quality monitoring after a flood to verify that water quality is not compromised	Advise the community to avoid using contaminated springs for drinking during and after floods, until quality has been verified

	contamination			areas.		
Run-off increases	Erosion	Permanent loss of borehole or well. Damage to the structure of the borehole or well, leading to a temporary loss of supply. Public health risk from contaminants entering the standpipe	Ensure that well heads are properly designed to prevent erosion damage that may increase infiltration. Use compaction of soils and planting around infrastructure to increase durability of structures	Maintain conditions which mitigate erosion e.g. compaction of soils and plants in buffer strips	Monitor microbial quality of water after the well or borehole has been renovated	Raise awareness among the community about the damage that erosion can cause to wells and boreholes. Develop communication procedures to notify the community when the water is safe

Septic tanks

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitori ng	Socioeconomic tools
Flooding increases; Increase in extreme rainfall events; run-off increases	Back flow of sewage into the house		Install non-return valve that can be shut in event of a flood; do not use the septic tank again until waters have receded	Regular emptying services to minimize faecal sludge build-up		Raise awareness about potential health issues associated with sewage
	Inundation of the system, resulting in contamination of surrounding area with sewage		Where possible, site tank away from water supply			Raise awareness about potential health issues associated with sewage
	Flooding of septic tank resulting in accumulation of silt		Design to prevent ingress of silt	Septic tanks and pump chambers can fill with silt and debris, and must be pumped out and cleaned after a flood. Ensure adequate access to tanks so that they can be cleaned		
	Flotation	Structural damage to tank, for example from movement	Use durable materials in construction of tanks			It is important that tanks are full of water during a flood to prevent damage to the infrastructure. However, lids need to be properly fitted and secured to prevent sewage overflow. Education and increased awareness of issues surrounding damage and when to replace
	Flooding of the absorption field with sewage sludge		Install non-return valve that can prevent flow to the field in event of a flood			
	Inundation of the soakaway		Delay using septic tank until flood waters and groundwaters have receded			Raise awareness of signs of failure of an absorption field, and how to fix it or construct a new one
	Erosion of soil around the tank and absorption field	Damage to infrastructure. Reduced efficacy of the absorption field	Planting of grasses and shrubs on the absorption area, and around the tank, to reduce erosion. Repair erosion damage and sod or reseed areas as necessary to provide turf grass cover. Build	Check the vegetation over the septic tank and soil absorption field after flooding		

			bunds (banks, dykes or levees) to divert flow away from system			
Groundwater tables rising	Flotation of septic tank	Damage to infrastructure		If groundwater rises above the bottom of the tank, the tank will need to be secured to prevent floating during pump out		Education and increased awareness of issues surrounding damage and when to replace
	Inundation of soakaway	Increased potential for contamination of groundwater. Treatment of sewage by soil in soakaways may be reduced Septic tank fills and backs up	Use shallower infiltration trenches or introduce artificial wetlands or reedbed systems to improve effluent treatment. Where possible, site system away from water supply. Design septic tank systems in conjunction with drainage to lower the groundwater table. Introduce trees and other plants to improve drainage and increase water loss by transpiration		Monitor water quality and groundwater levels	Education to increase awareness of the risks of sewage upwelling if soakaways are waterlogged. Ensure that septic tanks are emptied regularly

IMPROVED PIT LATRINES

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Flooding increases; Increase in extreme rainfall events; run-off increases	Pit overflowing or inundated; very mobile contamination	Faeces leaving pit and causing pollution downstream. Silt and solids entering pit and filling it	Design pit to allow regular emptying and post-flood rehabilitation to remove silt. Proper pit covers to prevent material flowing out in a flood. Investigate overflow mechanisms to filter water to reduce pressure build-up. Where possible, site latrine away from water supply, and away from areas prone to flooding. Build pit latrine superstructure at the same level as the houses, as these usually are above normal flood level. In urban areas, consider small pits which need regular (monthly or less) emptying to minimize the amount of faecal matter exposed to flooding. Consider if dry or composting latrines or sewerage is appropriate	Regular pumping or emptying of pit latrine (particularly in urban setting)	Monitoring and regulation systems should focus on emptying and faecal sludge management as well as construction of latrines – to ensure that systems are in place	Raise awareness about potential contamination of drinking-water supply and need for regular emptying
	Increased intentional emptying of pits during floods	Widespread contamination with faeces		Regular pumping or emptying of pit latrine (particularly in urban setting)	Monitoring and enforcement systems should focus on emptying and faecal sludge management, as well as construction of latrines – to ensure that systems are in place	Raise awareness about potential health issues associated with sewage. Raise awareness about potential contamination of drinking-water supply
	Inundation or erosion	Collapse of latrine	Site latrine away from drainage channel. Use durable materials in construction to protect pit covers. Proper compaction of soil around the latrine and presence of adequate base and earth filling to protect pits, pit covers and slabs. Install robust upper foundations, collar and footing to protect from erosion and flooding damage. Small pits in urban areas to minimize risk of collapse. Build bunds (banks, dykes or levees) to divert flow away from latrine. Planting of shrubs around the pit to reduce erosion damage. Adopt more conservative design standards for infrastructure to take higher and more frequent events into	Regular maintenance essential to limit vulnerability to collapse		Hygiene promotion. Education on regular maintenance requirements

			consideration (more expensive), or have systems that can be quickly and cheaply replaced			
	Damage to the superstructure		Make more durable, especially the bottom 30cm, or choose a cheaper temporary option that can be reinstalled rapidly			
	Latrine not accessible		Find a new site, not subject to such frequent flooding, or construct temporary latrines in refuges			
	Erosion	Collapse of latrine	Site latrine away from drainage channel. Use durable materials in construction to protect pit covers. Proper compaction of soil around the latrine and presence of adequate base and earth filling to protect pits, pit covers and slabs. Install robust upper foundations, collar and footing to protect from erosion and flooding	Regular maintenance essential to limit vulnerability to collapse		Hygiene promotion. Education on regular maintenance requirements
Groundwater tables rising	Inundation of the pit from below	Contamination of groundwater and soil, potentially reaching drinking-water resource	Provide protected water supply. Consider options: shallower pits and more frequent emptying; dry composting latrines; sewerage.	Regular pumping or emptying of pit latrine (particularly in urban setting) – link to smaller pit sizing	Monitor drinking-water quality	Education to increase marketing and user education of alternatives
	Inundation of pit	Pit collapse.	Build round pits instead of square to increase stability. Use durable materials in construction to protect pit covers. Proper compaction of soil around the latrine and presence of adequate base and earth filling to protect pits, pit covers and slabs. Install robust upper foundations, collar and footing to prevent collapse. Small pits in urban areas to minimize risk of collapse. Introduce trees and other plants to improve drainage and increase water loss by transpiration			Raise awareness about the dangers of unstable pit latrines, and under what conditions these might occur

COMPOSTING/DRY LATRINES

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Flooding increases; Increase in extreme rainfall events; run-off increases	Pit inundated	Faeces leaving chamber, leading to pollution in the environment	Design toilet to be appropriate to flooding levels (e.g. above ground chambers, rather than small pits)	Capacity to restart composting following event. Redress moisture balance		Ensure that users know they should keep moisture out after flooding
	Increased intentional emptying of pits during floods	See Pit Latrine				
	Inundation or erosion	See Pit Latrine				
	Damage to the superstructure	See Pit Latrine				
	Latrine not accessible	See Pit Latrine				
Groundwater tables rising	Inundation of the pit from below	See Pit Latrine		Capacity to restart composting following event. Redress moisture balance		Ensure that users know they should keep moisture out after flooding
	Inundation of pit.	See Pit Latrine		Capacity to restart composting following event. Redress moisture balance		Ensure that users know they should keep moisture out after flooding

Planned: Sewers

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Flooding increases; Increase in extreme rainfall events; run-off increases	Erosion	Same as improved Pit Latrines				
	Infiltration of flood water into sewer, leading to plug flow of pollutants and resuspension	Overloading of treatment works. Pollution of water resources downstream. Ingress of silt	Use sustainable urban drainage systems and separate sewers. Encourage decentralized systems	Clean sewers regularly. Clean drains regularly especially just before wet season	Monitor silt levels, blockages, crossconnections and so on, in drains and sewers	Stop illegal connections to foul sewers
	Rising receiving water levels.	Overloading of sewers, leading to backing-up.	Shallow sewers. Flap valves.			
	High flows cause sewers to flood into environment and houses	Decrease diameter of pipes to attenuate and store water. Separate sewage and stormwater systems. Consider use of small bore or other low-cost sewerage options at local level to reduce costs of separate systems. Design decentralized systems to minimize impact of local flooding				Education about hygiene and cleaning up after flooding
	Treatment and pumping systems cannot work if electricity is affected		Ensure that sewers are gravity flow wherever possible. Low-cost and shallow sewers have much lower pumping requirements	Local decentralized treatment will reduce pumping costs and enable local responsive management when system is vulnerable to damage		
	Erosion exposing and damaging pipe work, especially simplified sewerage		Site pipe away from drainage channel. Compaction of soil and planting above sewers, under paved roads etc. Adopt more conservative design standards for infrastructure to take more severe and more frequent extreme weather events into consideration (the more expensive option), or have systems that can be quickly and cheaply replaced	Low-cost sewers can be more easily maintained or replaced when damaged, but are more vulnerable to erosion. Have spare parts available		
Groundwater tables rising	Sewer surrounded by water	Overloading. Damage to sewer (scouring or washout of bedding, and flotation leading to cracking of the sewer pipes)	Do not locate sewers in soils which are regularly waterlogged. Low-cost and shallow sewers may be less susceptible and above groundwater levels			

Appendix D: Kenya Climate Brief

KENYA CLIMATE CHANGE BRIEFING

Temperature

The mean temperature is predicted to increase in Kenya with a greater frequency of hot days and nights

Rainfall

Rainfall is predicted to remain the same but shift in seasonality ('short' rains increase in duration, 'long' rains decrease) and increase in intensity

Extreme Events

An increase is expected in the frequency and intensity of extreme events, primarily droughts and floods. Expect extreme events to occur in new locations.

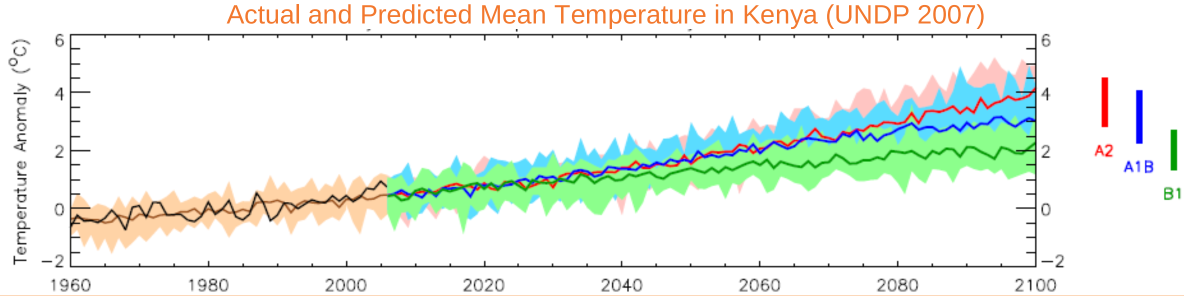
Overview

Kenya has a tropical climate moderated by diverse topography in the west. The central highlands are substantially cooler than the coast and temperatures vary little throughout the year – dropping 2°C in the coolest seasons (June to September). Rainfall is driven by the migration of the Inter-Tropical Convergence Zone and occurs in two distinct wet periods – the 'short' rains (October to December) and the 'long' rains (March to May). During these seasons the rainfall received is generally 50 - 200 mm per month, exceeding 300 mm in some locations. The onset, duration and intensity vary considerably each year. Kenya is very sensitive to fluctuations in sea-surface temperatures in the tropical Atlantic and Indian Oceans, which in turn are loosely coupled to the El Niño Southern Oscillation; in El Niño years the 'short' rains are longer and there is flooding whilst in the alternate La Niña years the 'long' rains are drier and there may be droughts.

Climate Change

Observational evidence from all continents and most oceans show that many natural systems are being affected by climate change, particularly temperature increases. The mean temperature in Kenya has been steadily increasing since the 1960s (see the graph below), however minimum temperature shows the most rapid increase, reducing the diurnal[1] range; the exception is in areas near large water bodies (for example Lake Victoria) where minimum temperatures have remained constant and maximum temperatures have increased (increasing the diurnal range). In recent years, the season of the 'short' rains has extended while the 'long' rains have decreased in both duration and intensity (MENR, 2009). The graph below also summarises the mean temperatures predicted by 22 Global Climate Models (GCM). Their range is indicated by the shading and the lines refer to three emissions scenarios – A2 (high), A1B (medium) and B1 (low) (describing future global economic growth and energy usage). The GCMs predict by 2090 annual mean global temperatures will increase by 1.3 – 4.5°C (there has been no regional downscaling of the GCMs for Kenya). Total rainfall is predicted to remain the same but the rainfall intensity is projected to increase, associated with the increase in atmospheric water vapour. In addition, the number of extremely wet seasons is projected to increase to 20% (i.e. 1 in 5 seasons) resulting in more flooding. The change in climate that occurred between 1960 and 2003 and the climate changes predicted by 2060 and 2090 are summarised in the table below.

Actual and Predicted Mean Temperature in Kenya (UNDP 2007)



	Observed (between 1960 and 2003)	Changes Predicted by GCMs by 2060	2090
Temperature Rise	1.0°C (0.21 per decade)	1 – 2.8°C	1.3 – 4.5°C
'Hot' Days[2] current climate (% of days)	-	17 – 45%	23 - 75 %
'Hot' Nights current climate (% of days)	-	32 -75 %	40 – 95%
'Cold' Days[3] current climate (% of days)	-	2 – 5 %	1 – 3%
'Cold' Nights current climate (% of days)	-	0	0
Precipitation[4]	No change	No large changes	
Heavy Rainfall Events[5]	Possible increase (not statistically significant)	Increase annually, but mainly in rainy season	
Maximum 1- and 5-day rainfalls	Inconsistent (not statically significant)	Increase in magnitude in rainy season	

[1] The temperature difference between the minimum at night and the maximum during the day

[2] 'Hot' day or 'Hot' night is defined by the temperature exceeded on 10% of days or nights in the current climate of that region (average)

[3] 'Cold' days or 'Cold' nights are defined as the temperature for the coldest 10% of days or nights (average)

[4] Model simulations show wide disagreements in projected changes in El Niño (strongly influences seasonal rainfall), contributing to the uncertainty in projection of rainfall, particularly the future inter-annual variability

[5] A 'Heavy' event is defined as a daily rainfall total in the top 5% of daily totals in the current climate of that region

Cranfield UNIVERSITY

WSUP Water & Sanitation for the Urban Poor

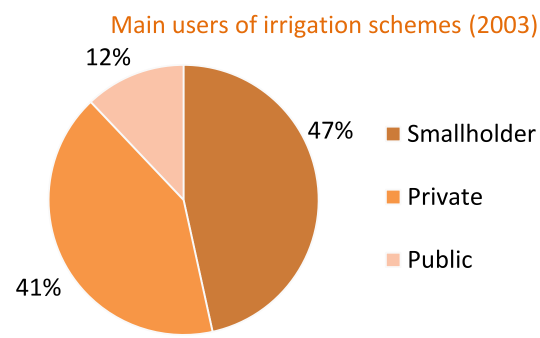
Water Resources

Kenya is classified as a chronically water-scarce country (8.3% of countries, WB 2009) and has one of the world's lowest per capita water replenishment rates (647 m^3 per capita per year, projected to decline to 235 m^3 by 2025, Olago, 2009). Despite this water scarcity there has been limited development of the available water resources – only 9% is utilised. As a result the water storage per capita has declined from 11.4 m^3 in 1969 to 4.3 m^3 in 2006 – principally due to population growth, thus during droughts the volume of water stored decreases rapidly and those dependent on surface water resources very quickly experience water shortages. There are 5 main drainage basins in the country but water is not distributed evenly, so only 2 have surplus water, the rest rely on transfers (canals). Out of 164 sub-basins with perennial river flows, 90 will suffer from surface water deficits by 2010 while 33 sub-basins without perennial river flow already have an apparent water shortage (FAO, 2005). As a result water use conflicts among irrigation, livestock, wildlife and environmental conservation is quite common. This is exacerbated by the long term degradation of catchments, lakes and aquifers (costs the country 0.5% of its GDP annually (WB, 2009)) and an uneven spatial and temporal distribution of resources, making the country very vulnerable to perturbations in water supply, particularly from climate variability (World Bank, 2009). In addition, groundwater resources have been exploited beyond their sustainable yield in the intensively settled parts of the country (in Nairobi the groundwater has been steadily declining). The table above summarises the water resources in the country.

AQUASTAT FAO (2010)	Date	Value	Unit
Water Resources			
Long-term average annual precipitation		365	km^3/year
Long-term average annual renewable water resources			
Internal		20.7	km^3/year
Surface water		20.2	km^3/year
Total Dam Capacity	2003	4.08	km^3
Ground water		3.5	km^3/year
External (imported water)		10	km^3/year
Total		30.7	km^3/year
Total renewable water resources per capita	2008	792	m^3/year
Water Withdrawn			
By sector			
Agricultural	2003	2.165	km^3
Municipal	2003	0.47	km^3
Industrial	2003	0.1	km^3
Total Freshwater Withdrawal	2003	2.735	km^3
Total water withdrawal per capita	2007	72.44	m^3
Pressure on water resources			
Total freshwater withdrawal as percentage of actual renewable water resources	2007	8.909	%
Agricultural water withdrawal as percentage of actual renewable water resources	2007	7.052	%

Irrigation

About 80% of the country is arid and semi-arid, 17% is considered high potential agricultural land which sustains 75% of the population. Is predominantly rainfed, but it is still the main user of water and currently consumes about 80%, while municipal and commercial use accounts for the rest (17% and 3% respectively). About 80% of all people working in agriculture are smallholders (breakdown of irrigation right). Currently irrigation development is lead by the private sector and by smallholder irrigation schemes with great emphasis on sustainable development (AQUASTAT, 2010).



Drinking Water and Sanitation

Until its recent political setbacks, Kenya appeared to be on track to achieve the Millennium Development Goal (MDG) of 90% water access, though it was off-track to meet its 90% target for sanitation access (USAID, 2009). There are 1800 municipal water supply schemes, out of which 700 are managed by the Ministry of Water Resource Management and Development while communities manage the rest. There are 9000 boreholes, most of which require rehabilitation. The table below summarises the improvements to water and sanitation in urban and rural Kenya (Joint monitoring programme WHO & UNICEF, 2009)

Year	Urban Population (millions)	Rural Population (millions)	Improved Water Supply (%)			Improved Sanitation (%)		
			Urban population	Rural population	Total	Urban population	Rural population	Total
1990	4.3	19.1	91	32	43	24	27	26
1995	5.2	22.2	89	38	48	25	28	27
2000	6.2	25.2	87	43	52	26	30	29
2005	7.4	28.2	85	48	56	27	31	30
2008	8.3	30.4	83	52	59	27	32	31

MAIN IMPACTS OF CLIMATE CHANGE

Agriculture is the basis of the Kenyan economy and it is very vulnerable to increasing temperatures, droughts and floods, which result in a reduction in maize yields (requiring significant imports), the number of livestock (shortage of forage, increased disease and lack of water) and the output of every major sector of the economy (costing 2.4% of GDP per annum). The arid and semi-arid lands (80% of the country) are particularly vulnerable as their economy is almost entirely dependent on livestock. The population stresses will increase migration which will typically be to urban areas. The increased populations in urban areas will increase competition over natural resources and the likelihood of conflict. In addition, resource scarcity can lead to increased capture of resources by elites exacerbating exiting inequalities. The table below summaries the main impacts of climate change.

	Increased Temperature	Droughts	Floods	Sea Level Rise
Water	• Increase evaporation, decreases hydroelectric potential	• Water scarcity • Lower groundwater • Reduced hydroelectric production[1] • Increased reliance on Imported water • Saline intrusion • Increased vendor water costs • Increased time fetching water • Increased pumping costs	• Detrimental impact on water quality (eutrophication from dissolved fertiliser) • Sedimentation	• Saline intrusion • Increase in flooding and extreme weather
Livelihoods	• Crop failure and food insecurity • Change in livestock • Lower maize yields[2] • Reduced production of tea, sugarcane, and wheat • Crop pests more common • Wildlife extinction • Decline in fish stocks	• Death of livestock[3] • Human-wildlife conflict • Conflict between pastoralists and famers • Erosion of top soil and grass seed • Decline in vegetable production • Damage to tourist attractions/ wildlife • Grazing land competition • Increased competition at fishing grounds[4] • Reduction in aquaculture production • Food prices increase at rural markets	• Eroding and washing away of grass seed and topsoil • Destruction of infrastructure (roads, rail, bridges, irrigation, pipes) • Crop loss • Livestock loss • Agriculture and schooling disrupted • Damage to tourist attractions/wildlife • Siltation/destruction of sand dams • Redistribution of nutrients	• Land submerged[5] • Erosion of shoreline damaging infrastructure • Damage to tourist attractions/wildlife • Crops lost
Health	• Increase in rift valley fever[6] • Spread of Avian influenza, cholera, ebola, Lyme's disease, plague, tuberculosis, sleeping sickness, yellow fever, red tide and babesiosis	• Starvation[7] and malnutrition • Less water for hygiene and cleaning, increasing water-washed diseases • Increase in water-borne diseases through deterioration of drinking water quality	• Cholera epidemics • Loss of life • Increase in water-borne diseases • Damage to health infrastructure • Food shortages	
Biodiversity	• Deforestation[8] • Reduction in growth and regeneration • Reduced biodiversity • Desertification • Forest land degradation • Invasive species • More frequent forest fires[9] • Extended range of pests • Species range shift extinction of species	• Forest fires • Mangroves die back • Increased charcoal production, forest clearing and logging • Increase in disease • Desertification	• Sedimentation • Loss of habitats • Soil erosion	• Food shortages • Mangroves submerged • Displacement of coastal wetlands • Bleaching of coral reefs

[1] During the drought in 1999/2000, hydropower generation was reduced by over 40%, and Kenyan industry lost Ksh 110 billion (World Bank, 2009)

[2] In 2000 national maize production (staple crop for 90% of the population) declined to 2 million tons from 2.3 million tons in 1999 and the Government had to import 2.6 million bags of maize worth $800 million (MENR, 2009)

[3] Livestock is 12% of GDP and forms 47% of agricultural GDP. In the arid and semiarid lands (80%) livestock accounts for 90% of employment , 95% of income and there are high rates of poverty (60% of families). During the 1999/2000 drought economic loss from livestock deaths was Ksh 11 billion (Kabubo-Mariara, 2009)

[4] When there are no jobs in farming, industry, and tourism, people resort to fishing for subsistence (fishing activities increased more than ten-fold during the 1999/2000 drought (NIDOS, 2009))

[5] The Kenyan coastline is said to be one of the most vulnerable to sea level rise in the world (if the seas rise by only 0.3 m, 17% of Mombasa will be submerged (4600 ha))

[6] Occurs during periods of high humidity, killing livestock (MENR, 2009)

[7] The 1999/2000 droughts resulted in 4.7 million facing starvation

[8] 68% of households use fuel wood as their main energy source for cooking and heating (MENR, 2009)

[9] Over last 20 years Kenya has lost more than 5,700 ha of forests per year to forest fires (MENR, 2009)

Vulnerability Assessment

A range of global and regional studies have assessed Kenya's vulnerability to climate change using global datasets(1,2,3,4,5) producing indices for each country to enable simple comparison. The table below presents the scores (measure of vulnerability) for Kenya for 9 global indices. The indices, which assess the impact of climate change on water resources, indicate that Kenya only has a medium vulnerability. This is likely a result of the indices being distorted by the larger amounts of water available in the 2 wet catchments - in the arid and semi-arid lands there is chronic scarcity and low utilisation of water resources and climate change will be a major problem. Kenya has a reasonably low social vulnerability indicating that the government and economy are reasonably stable and relatively able to adapt to climate change.

Index	Score	Vulnerability	How it's calculated
Water Resources			
Water Scarcity Index (2004)[1]	0.5	Medium	Water extracted from rivers divided by the low flow (flow exceeded 90% of the time). E.g. If ≥ 1 then consumption exceeds supply
Ground Water Dependence (2004)[1]	0.25	Medium	Ground water withdrawn as a fraction of total water withdrawn in region
Total freshwater withdrawal as percentage of total renewable freshwater resources (2009)[2]	8.9%	Medium	Total freshwater withdrawn in a given year, expressed as percentage of the total actual renewable water resources. It is an indication of the pressure on the renewable freshwater resources (data from 1998-2002)
Annual Renewable Water Supply per capita (Projections for 2025)[2]	840 m^3/capita	Scarcity	Runoff (data from 1950-2000) divided by Population (2025) (prediction from UN population division)
Social Vulnerability (1st = lowest vulnerability)			
Human Vulnerability A (2007)[3]	0.578	30th /49 (Africa)	Social vulnerability to climate change (the index consists of 5 weighted factors, each of which is scored). In HVA the factors are: economic well being and stability (20%), demographic structure (20%), global interconnectivity (10%) and dependence on natural resources (10%); HVB also includes institutional stability and infrastructure (corruption) (40%)
Human Vulnerability B (HVB, includes corruption) (2007)[3]	0.603	11th / 49 (Africa)	
Sensitivity and Adaptability (2007)[4]	0.541	147th / 182 (global)	Human Development Index (used as generic indicator for adaptive capacity)
Sensitivity Index (2004)[1]	3	Medium	Combination of Water Scarcity Index, GW Dependence and Sensitivity and Adaptability Index
Climate Vulnerability Index (2007)[5]	-	Medium-High	The index links water resource modelling with human vulnerability assessments to contribute to a meaningful assessment for generic use

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Appendix E: Kenya Climate Proofing

How to Climate Proof Water and Sanitation Services in the Peri-Urban Areas in Naivasha

WSUP
Water & Sanitation for the Urban Poor

Cranfield UNIVERSITY

How to Climate Proof the Water and Sanitation Services in the Peri-Urban Areas in Naivasha

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August 2010
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Work based on field visit to Naivasha undertaken in July - August 2010

Cover Photo: Alison Parker 2009

Disclaimer
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Reference
Heath, T., Parker, A., & Weatherhead, E. K. (2010). How to climate proof water and sanitation services in the peri-urban areas in Naivasha. Report prepared by Cranfield University. WSUP, London.

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Executive Summary

This report evaluates the impacts of climate change on water and sanitation technologies in the peri-urban areas around Lake Naivasha, reviews the water resources in Lake Naivasha and considers the potential adaptations required to mitigate the impacts. Under current forecasts of climate change, the mean temperature in Kenya is predicted to increase while precipitation is expected to decrease in volume and increase in intensity, increasing the frequency and severity of droughts. The impacts of climate change were assessed using two scenarios (to account for the uncertainties associated with climate change): Decreasing lake and ground water levels and Increasing lake and ground water levels. The main impacts are as follows:

- **Decreasing lake and ground waters:** will have a significant impact as there will be higher domestic demand whilst surface water availability decreases. During droughts there are longer queues, water from vendors is more expensive and it takes longer to collect. As a result, water use decreases, hygiene deteriorates and disease increases. The lake area reduces and there is increased conflict between pastoralists and farmers; tourism and fishing suffers, there is reduced employment (in particular from the flowers and vegetable farms as they are less profitable to run) and the lake's quality deteriorates. The main problems cited by the community during previous drought were a decrease in income and the increased cost of food and water. There was little impact on the borehole supply (as it is a confined aquifer) and latrines

- **Increasing lake and groundwater levels** is largely positive for Naivasha as there is more water for domestic and irrigation use. The main problem is an increase in the number and intensity of flash floods. This increases the amount of solid waste and silt washed into the lake, causes latrines to collapse and overflow, exposes pipes, damages houses and crops and inundates roads which disrupt local business. However, flash floods are only an inconvenience to the community as they are able to harvest the increase in rainwater, but there is an observable increase in disease

Potential short, medium and long term adaptations are identified for WSUP (or the local provider), NAIVAWASS and the City Council. The adaptations were determined based upon a field visit, a vulnerability assessment and a literature review. The key recommendations (some are already being undertaken) are as follows and should be implemented within a Water Safety Plan:

WSUP

- Ensure affordable and accessible water supply
- Support catchment management plan
- Latrine construction and education to prevent collapse and overflowing
- Protect boreholes ensuring well head properly sealed and fenced
- Educate community on flood prevention and mitigation strategies
- Replace high lift pump at borehole in Kamere
- Education on the need to site latrine away from drainage channel, ensure proper seal when constructing pit latrines and build latrines with doors facing down slope
- All construction below ground from stone/bricks, possibly use properly compacted sand blocks
- Monitor water level in boreholes during droughts and floods

NAIVAWASS

- Incorporate kiosks system into distribution network
- Adapt the system to increase the resilience to flash floods, in particular the sewage system

COUNCIL

- Maintain, improve and develop drainage systems
- Terracing and tree planting in the upper catchment
- Support Water Allocation Plan when it is updated

Contents

Introduction

"Observational evidence from all continents and most oceans shows that many natural systems are being affected by climate change, particularly temperature increases" (IPCC, 2007). This report outlines the impacts (both direct and indirect) associated with the climate changes predicted for three peri-urban areas around Lake Naivasha.

It starts by reviewing the water resources in Lake Naivasha, the regulations, hydrology, hydrogeology and pollution of the lake. It then reviews the impacts of the climate scenarios predicted for Kenya; the indirect impacts of climate change and the impact upon Lake Naivasha. It then synthesises how the climate scenarios will affect the existing vulnerabilities, problems and technology in the peri-urban areas in Lake Naivasha. The report concludes by outlining the main adaptations required in the peri-urban areas by WSUP, NAIVAWASS and the local council, dividing them between short, medium and long-term adaptations. The key climate studies and researchers for Lake Naivasha are also listed.

The report aims to provide pragmatic recommendations for adaptation; focusing upon what is known rather than the uncertainties. The document should be read alongside the Kenya Climate Briefing (Heath, 2010).

Method

The research started by identifying literature on the impacts of climate change on water and sanitation technologies. The key document was a review completed by the WHO and DFID in 2010 (Charles *et al*., 2010). This describes the vulnerabilities of various water and sanitation technologies to climate change, and proposes adaptations. This was followed by a field visit which identified which technologies are being used in Lake Naivasha and hence identified the vulnerabilities of the water and sanitation system to climate change. The adaptations required to mitigate these vulnerabilities were selected from Charles et al (2010) and are listed in the appendix.

The field visit to Lake Naivasha, was completed in July 2010 and entailed 27 semi-structured interviews with members of the community and representatives from the local service provider, water utility, local Council, regional government, scientific community and NGOs (Table 3 in the appendix lists the interviewees). The interviews and observations assessed the impact of flooding and droughts on the existing environmental, social and economic vulnerabilities and the impact on technologies. The interviews also assessed the institutional awareness of climate risks. Further climate vulnerabilities were identified from the literature review. Two focus groups were undertaken with the community, to do a cause and effect analysis (i.e. what are the problems, what causes them and what impacts do they have).

The information gathered from the interviews was used to prepare a vulnerability assessment. This involved listing the problems identified in the peri-urban areas and identifying the linkages between them in a flow chart (e.g. flash floods can lead to buildings collapsing). Once the linkages between all of the problems had been identified, the expected changes in climate were added (e.g. decreasing rainfall) and the factors they impacted (directly and indirectly) were identified. In addition, the indirect impacts of climate change (e.g. food insecurity) were incorporated assessing which factors they affected. This made it possible to assess how climate change will affect the existing vulnerabilities in the peri-urban areas (see Appendix – Figure 4). This diagram was then used to determine the adaptations required to mitigate the problems.

The adaptations from both the fieldwork and the literature review were then amalgamated and assigned to the WSUP, NAIVAWASS and local Council, dividing them into short medium and long term adaptations.

Lake Naivasha

The lake is the basis of the economy in Naivasha. It provides freshwater for flower and vegetable farms (4000 ha), fishing and tourism opportunities. The horticulture and floriculture industries in Naivasha are highly profitable and expanding, which attracts new populations looking for employment and typically leads to poor housing, social friction and exploitation (Becht, 2007). The local populations are quite hostile towards the flower farms, blaming them for over abstraction, pollution and exploitation of workers. In reality the majority of pollution comes from the small farms in the upper catchment. *"80% of the reduced lake levels can be attributed to the irrigated horticulture around the lake while 80% of the inflow of pollutants and nutrients can be attributed to the farmers in the upper catchment"* (Becht, 2007, p24).

There are a large number of stakeholders working around the lake. In recent years there has been improved cooperation between them and they are now working towards better management of the catchment. An abundance of scientific research has been undertaken on the lake (more details in references) –especially from the ITC[1] lead by Robert Becht. The lake was designated a RAMSAR site (wetland of international importance) in 1995 as it is the largest freshwater reservoir in the Rift Valley, acting as a refuge for wildlife and it contains the largest number of water birds in Kenya (more than 20,000) (RAMSAR, 1995). A Water Allocation Plan (WAP) was developed in 2010 for Naivasha Basin by the Water Resource Management Authority in collaboration with the major stakeholders. The WAP establishes a framework for the allocation and abstraction of water resources for the entire basin; attempting to balance consumptive use with environmental and human rights. The WAP is based on the limited hydrology data available for the lake and recognises its accuracy is a major constraint to the plan. It recommends future editions are made on the basis of more accurate and comprehensive data (WRMA are investing in gauging stations and local gauge readers). The WAP links water allocation to the availability of the resource, restricting abstractions based on the lake, river and groundwater river levels (classifying the resource as satisfactory, stressed, scarce or reserved - Table 1). The WAP runs to 2012, when the plan will be evaluated and updated by a process described in the WAP. The WAP does not incorporate climate change and this should be amended in future versions. The WAP should

[1] ITC - Faculty of Geo-Information Science and Earth Observation, University of Twenty, Netherlands

improve the sustainability of the resource, particularly important as many of the majority of stakeholders fail to recognise the link between the groundwater and lake level assuming an abundant supply of groundwater.

Table 1 Rules for Water Abstraction Restriction (there are additional restrictions for River flows (WRMA 2010)

Abstraction Restrictions and Reserve Water	Lake Naivasha level (mAOD)	Lake Water Abstractions	Groundwater Abstractions
Green i.e. Satisfactory: *Abstractions allowed up to permit limits*	> 1885.3	- Domestic and public water supplies - Others draw 75% of their licence	
Amber i.e. Stress: *Slight abstraction restrictions imposed*	1885.3 to 1884.6	- Domestic and public water supplies. - Others draw 75% of their licence	
Red i.e. Scarcity: *Severe abstraction restrictions imposed*	1884.5 to 1882.5	- Domestic and public water supplies draw 75% of licence - Others draw 50% of their licence	
Black i.e. Reserve: *Full protection; surface water uses restricted to basic human / livestock needs and nature (ecosystem) only*	< 1882.5	- Domestic and public water supplies draw amounts for basic body needs only i.e. 25 litres per person / livestock unit per day	- Domestic and public water supplies draw 75% of licence - Others draw 50% of their licence

WATER RESOURCES

This section draws heavily on work by Robert Becht (ITC) and the Lake Naivasha Riparian Association (Becht, 2005 et al. & 2007)

Lake Naivasha's water level has varied 12 m in the last century. The lake is fed by two perennial rivers (Figure 1), the Malewa and the Gilgil, providing 80% and 20% of the total inflow respectively (the areas south and west of the lake do not produce much runoff that reaches the lake lake). The rivers have good water quality with a low level of total dissolved solids, but the level of sodium in the water is relatively high. The lake's catchment receives an average rainfall of 600 mm/year the majority falling in the upper catchment. The lake fills a shallow depression (the main lake has a maximum depth of 8m), therefore its area and evaporation loss increases with rising lake levels (Becht, 2007). The lake has no surface outflow and the largest loss is from evaporation (approximately 1700 mm/year). The lake does not become saline as there is ground water flow to the shallow aquifer (recharging a deep geothermal aquifer system and other lakes in the region – taking around 1000 years to reach them). A water balance was developed for the period 1934-2006 by the ITC and Lake Naivasha Riparian Association (LNRA) (Table 2). It modelled the lake level accurately up to 1983 (95% of levels differed by no more than 0.52 m), but beyond this the modelled flow was 3 meters higher than the observed level (Figure 2). The discrepancy coincided with the commencement of horticulture in the basin and the estimated abstractions from surface and ground water closely matched the annual modelled deficit (60

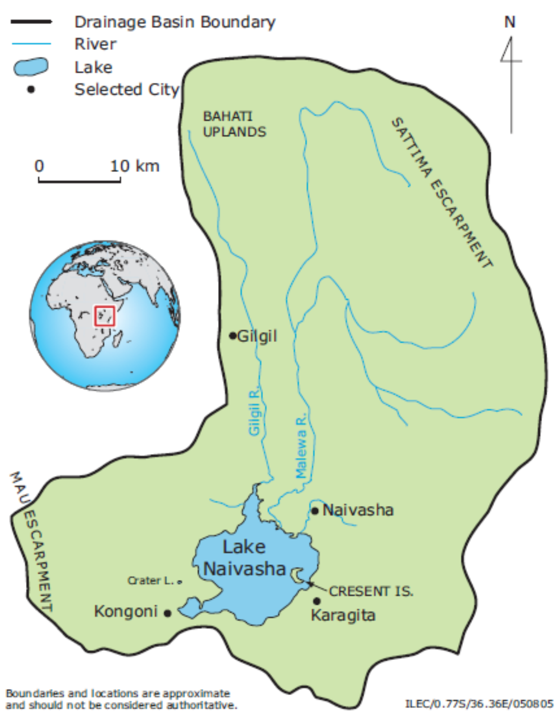


Figure 1 Map of Lake Naivasha catchment (Becht et al., 2005)

million m^3)(Becht (2007) provides a review of the impact of the flower farms on the Lake). When the abstractions were incorporated into the model it matched the observed level. The model indicates that if a drought similar to 1940 occurred the lake's area would reduce from the present 120 km^2 to 30 km^2.

Table 2 Lake Naivasha water balance in M m^3 (10^6 m^3/Month) 1934-1983 (LNRA, 2006)

Rain	Surface water inflow	Evaporation	Groundwater outflow
95	220	260	55

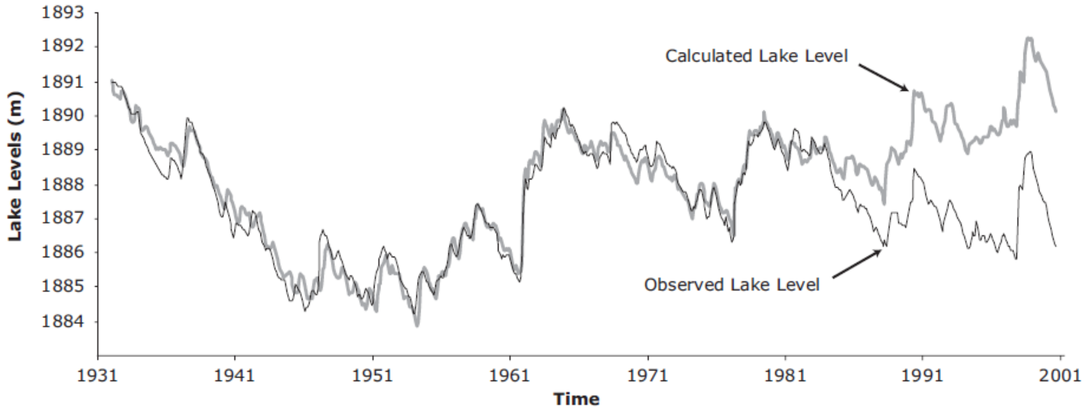


Figure 2 Long-term water change in Lake Naivasha, observed and modelled lake level (LNRA, 2006)

Groundwater has an important effect on the water balance for the lake - when the lake levels are high the lake recharges the surrounding aquifer and when low, the aquifer discharges into the lake. This interaction means there is a delay between meteorological stresses and changes in lake levels (LNRA, 2006). The groundwater acts as an extra reservoir, absorbing water during wet periods and releasing water during droughts. The aquifer has a very high transmissivity (pumping tests have yielded more than 10,000 m^2/day and the specific yield is 0.15 (Betch and Nyaoro, 2006). Due to the high transmissivity the gradient of the water table is low and the water table extends almost horizontally into the aquifer (Figure 4). There are some inflows from the flanks of the Rift Valley and major groundwater flows to the north and south drain away from the lake (Figure 3). There are significant groundwater abstractions north of the Lake, these have caused the natural gradient to inverse and a ground water depression to form – reaching a depth 6m below the lake (i.e. water flows from the lake towards the pumped zone - Figure 4). Groundwater movement is important in the area as it's used for supplying drinking water, transports pollutants and affects the levels.

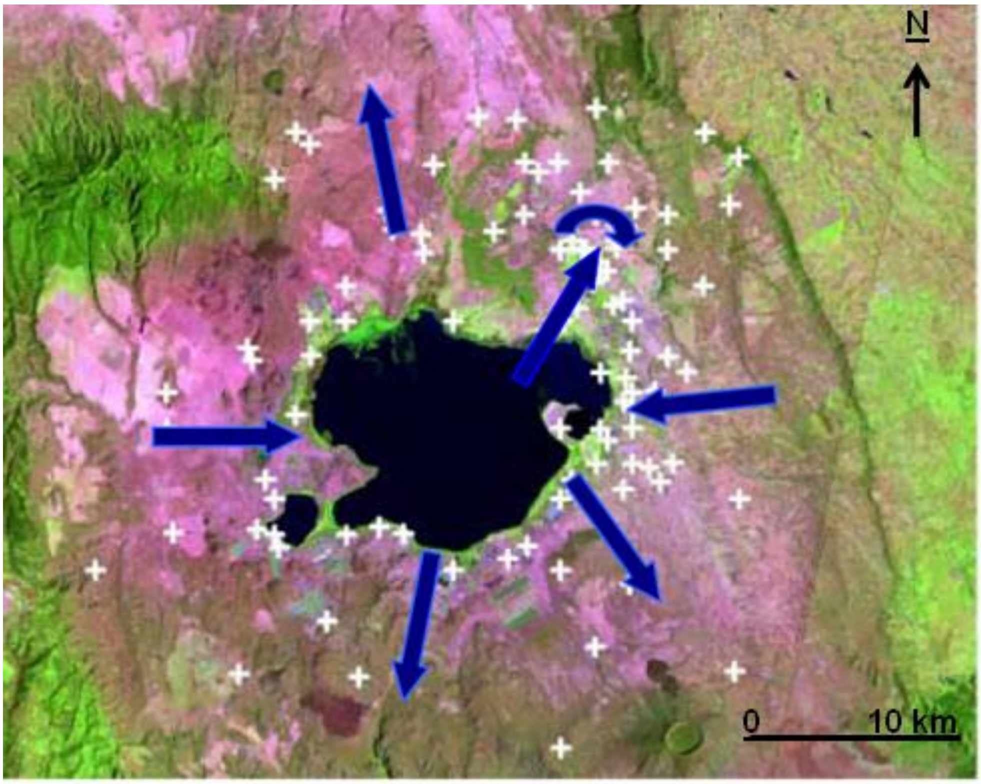


Figure 3 Lake Naivasha with wells (+) and general direction groundwater flow, reverse arrow represents return flow (figure 4c) (adapted from Becht & Nyaoro, 2006)

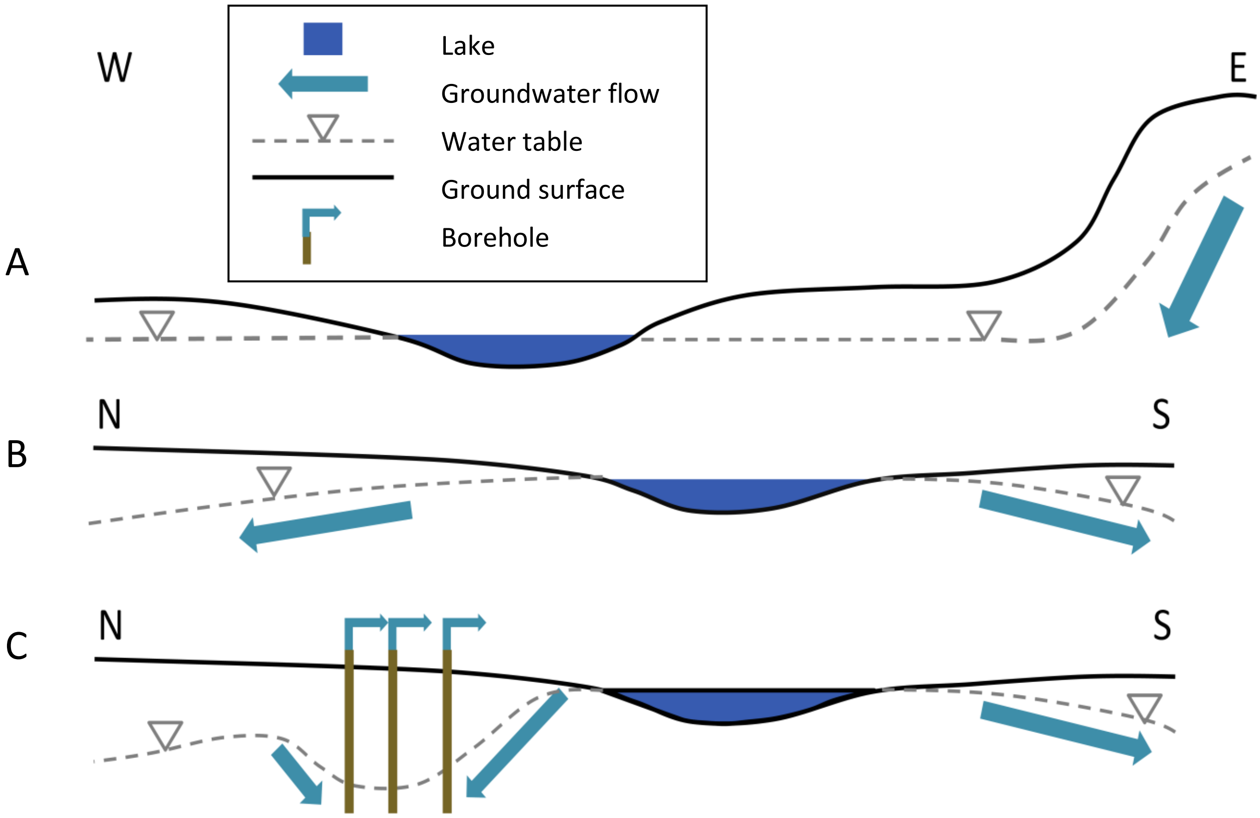


Figure 4 Cross Sections of Lake Naivasha showing water table West to East (A) and North to South before (B) and after pumping (C) (not to scale)

POLLUTION OF THE LAKE

The lake environment has been severely degraded due to pollution, eutrophication, siltation and invasive species. Pollution is primarily from excess chemicals and manure applied in the upper catchments (steep slopes, high rainfall and impermeable soils) and sewage from around the town (Becht, 2007). Little pollution enters the lake from the floriculture and horticulture surrounding it, as there are permeable soils, gentle slopes and it is semi arid[2] (little direct runoff), however, agrochemicals are constantly transported downwards into the groundwater. Due to the groundwater flow paths if water is abstracted in the north it will return to the lake (as well as any pollutants) and be reused. In the south there is greater reliance on surface water (groundwater is more saline as the aquifer is deeper) and over irrigation leads to a net water loss as groundwater moves away from the lake. A review by Harper (2004) found that the ecology of the lake had been most severely disrupted by invasion of alien species – particularly the *Louisiana* crayfish and destruction of the papyrus vegetation (filters nutrients and sediment, provides a nursery and habitat). The destruction is most prevalent in the north of the catchment, where the main tributary enters; the area used to function as swamp, but now silt and nutrients run straight into the lake. Deforestation is a very significant issue in the catchment and is the cause of a lot of the eutrophication and siltation – the Naivasha council has a large tree planting programme to try and remediate the impacts.

[2] In addition as the flower and vegetable farms supply Europe they are regulated by EU standards, which have strict environmental requirements

Impacts of Climate Change on the Peri-Urban Areas

Kenya is classified as a chronically water-scarce country and has one of the world's lowest water replenishment rates per capita (World Bank, 2009). Agriculture is the basis of the economy and it is very vulnerable to increasing temperatures, droughts and floods, which reduce maize yields, the number of livestock and the output of every major sector of the economy. The arid and semi-arid lands (80% of the country) are particularly vulnerable as their economy is almost entirely dependent on livestock. The changes to climate expected are as follows (refer to the Kenya Climate Briefing - Heath, 2010 - for a more in depth overview):

CLIMATE CHANGES

Based on UNDP (2008), NAPA (2003), UNFCCC (2003) and discussions with Kenya Meteorological Organisation (2010):

- Temperature: the mean temperature is predicted to increase in Kenya with a greater frequency of 'Hot' days[3] and nights and very few 'Cold'[4] days or nights
- Rainfall: changes in rainfall are less certain, rainfall is anticipated to decrease in volume, increase in intensity and become increasingly irregular (observable in recent years)
- The climate is affected by strong ENSO event - El Niño is associated with increased rains throughout the year and La Niña is associated with a drier seasons – while a weak ENSO event has little influence on the climate
- Extreme events: anticipated increase in the frequency and intensity of extreme events, primarily droughts and floods. Extreme events are expected to expand their range of influence and there will be a shorter growing season in some regions

[3] Hot' day or 'Hot' night is defined by the temperature exceeded on 10% of days or nights in the current climate of that region (average)
[4] 'Cold' days or 'Cold' nights are defined as the temperature for the coldest 10% of days or nights (average)

Uncertainty

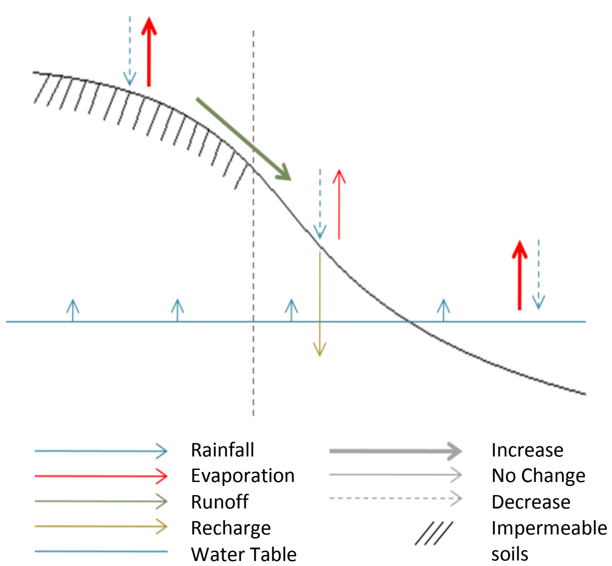
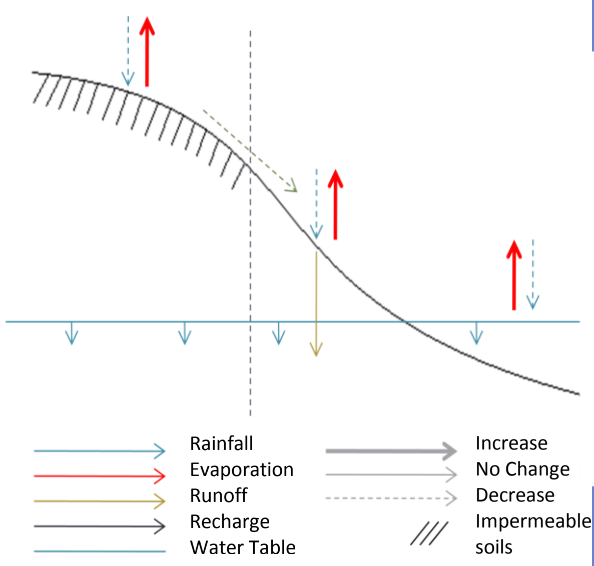
“One thing is certain; under climate change uncertainty will increase” UNWATER, 2009. When making climate change impact assessments, a ‘cascade’ of uncertainty arises (e.g. uncertainty with modelling, scenarios and data) making it difficult to make reliable predictions. The impacts predicted need to be considered alongside current population pressures and existing vulnerabilities - even without anthropogenic climate change, climate variability undermines food security, negatively affects the environment and significantly affects livelihoods. Therefore the most pragmatic adaptation is to develop the resilience of water and sanitation systems– managing risks, building their capacity to deal with unpredictable events and prioritising no-regret measures (UNWATER, 2009).

Climate Scenarios

To assess the impacts of climate change on the peri-urban areas surrounding Lake Naivasha, the impacts of increasing temperature, decreasing rainfall and increasing rainfall intensity were reviewed using two scenarios: increasing lake and groundwater levels and decreasing lake and groundwater levels. The differences in the scenarios are due to uncertainties with rainfall and evaporation (from soil and the lake). As it is not known how much rainfall intensity will increase or how much the total volume will decrease. This will affect the infiltration dynamics (in particular when the soil becomes saturated and rainfall can no longer infiltrate. The hydrology of the scenarios are summarised below (also outlined in Table 3 outlines how the hydrology would change for each and the key issues arising for water and sanitation technologies):

- **Increased Lake Levels:** Increase in rainfall intensity in the upper catchment results in increased runoff and river flow, offsetting the increase in evaporation at the lake and maintaining the lake level
- **Decreased Lake Levels:** Significant increases in evaporation from the lake (and irrigation demand); rainfall decreases and is more sporadic offsetting the increase in intensity and runoff

Table 3: Predicted changes to hydrology resulting from climate change (dashed arrows indicate a decrease, thick arrows an increase) and the key issues resulting from climate changes (the appendix summarises the impacts of the key issues on the technologies)

Increased Lake and Groundwater Level (increase in flash floods)	Decreased Lake and Groundwater Level (increase in droughts)
	
Impact on Water Supply • Increase in extreme rainfall events • Groundwater recharge increases • Run-off increases	**Impact on Water Supply** • Increase in extreme rainfall events • Water availability decreases

Sanitation	Sanitation
• Flooding increases; increase in extreme rainfall events	• Water availability decreases

IMPACTS OF CLIMATE CHANGE NOT DIRECTLY RELATED TO WATER AND SANITATION

The following summarises the impacts of climate change on Kenya not directly related to water and sanitation; refer to the climate change briefing (Heath, 2010) for a comprehensive overview:

- **Food insecurity – principally maize and livestock**: Increasing temperatures and the unpredictability of rainfall will increase crop failure, significantly increasing the cost of food – the drought in 2009 considerably increased the cost of food items in the peri-urban areas and was cited by the community as one of the main problems during the drought;
- **Employment –** the majority of employment in Lake Naivasha is from the flower and vegetable farms around the lake. If the lake is low the farms may reduce production and lay off workers (depending on the extent of the shortages and when the shortages occur in the growing season);
- **Electricity**: droughts and reduced rainfall decrease the availability of water for hydroelectric increasing the price of electricity and the cost of pumping water.

IMPACT OF CLIMATE CHANGE ON LAKE NAIVASHA

To assess the impact of climate change on Lake Naivasha the data used in the water balance model was modified to evaluate the sensitivity of the lake to changes in surface inflow, evaporation and rainfall and assess how the WAP abstractions would have differed calculated (The method and figures are presented in the appendix). The analysis indicated that the lake is more sensitive to changes in surface water inflows and evaporation than rainfall. Either a 10% increase in evaporation or a 10% percentage decrease in surface water reduces the lake level by a metre and significantly increases the number of months it is classed as scarce – from 5.2% of months to around 25%. If surface water inflows increase the lake level will increase and be classed 'satisfactory' for most months. This analysis indicated that surface water inflows have a significant effect on lake levels; therefore further studies should clarify how changing land use impacts inflows. Changes in rainfall have half the impact of changes in evaporation with a 10% reduction reducing the lake level by under a meter. Rainfall has less influence on the lake as it inputs half the volume inputted by surface water and removed by evaporation (95 M m^3 compared to 220 M m^3 and 260 M m^3, Table 2). If evaporation increases or surface water decrease coincided with a drought similar to the one of 1940 and current abstractions continue the lake would dry up - the new WAP limits should prevent this, but it highlights the significance of climate change and the need for sustainable management of the lake.

Impact of climate change on Peri-Urban Areas

Climate change is likely to exacerbate [or reduce] existing vulnerabilities rather than create new problems. Figure 4 synthesises how climate change will impact the existing vulnerabilities). The following outlines the impact of climate change on water and sanitation in the peri-urban areas around Lake Naivasha.

Decrease in lake and ground waters

Decreasing lake levels and drought will have significant impacts on the peri-urban areas in Naivasha. During droughts there is higher domestic demand (laundry and washing), but water availability decreases. At the kiosks and the free borehole 4 km from Kamere there are long queues, while in the unserved areas it takes longer to collect water from the lake, it is more expensive from vendors and there is increased use of low quality water direct from the lake. As a result water use decreases, hygiene deteriorates, there is an increase in diseases, it is more difficult to irrigate domestic gardens and women have to spend more time cleaning, washing and collecting water (in Kamere men also collect water). In addition, children are often sent looking for work instead of going to school (especially water vendoring which is quite profitable). If the whole country is suffering from drought then food and consumables are more expensive and hydroelectric sources have insufficient supply increasing the cost of electricity and the cost of pumping water. During interviews the community almost exclusively cited the increased cost of food and water, combined with unemployment as the most significant issue during droughts. The boreholes supplying the kiosks in Karagaita are in a confined aquifer and the yield was not significantly affected by the 2009 drought. The water level in NAIVAWASS boreholes (3 next to the lake) was lower and volcanic soil was deposited in the tanks. In Mirera the borehole level was not significantly affected during the drought.

Impact on Employment

Decreasing lake levels create a large number of problems for the flower and vegetable farms:

- The concentration of pollutants in the lake increases, making alga blooms more likely, increasing the cost of filtering the water;
- The lake's shallowness means as the level lowers its area contracts and abstractions are no longer at the lake edge; to adapt the flower farms dig trenches to access the water, which act as barriers to wildlife and livestock;
- If the groundwater is lower it is more expensive to pump and becomes increasingly saline;
- As there is less water in lakes the farms abstract less as they feel it's not sustainable. The result is the financial viability of the farms decreases (especially the south side) and they reduce production and employment, significantly affecting the peri-urban areas.

The WAP will limit abstractions when the lake is low, therefore the farms need to increase the water efficiency or they will be forced to reduce production. The flower farms are investing in hydroponics[5] and more efficient water use, reducing their vulnerability, while the vegetable farms still have a high water demands.

Impact on Livelihoods

Fishing, livestock and tourism will also be affected by declining lake levels. Fisheries would be severely affected, as algal blooms reduce oxygen levels in the water leading to fish deaths, the fish nurseries are in the shallower parts of the lake which are exposed during droughts and the lakes' smaller area results in overfishing damaging future yields. Pastoralists are impacted by the declining lake edge and it becomes more difficult to reach water as the exposed riparian land is used for farming or trenches and wildlife corridors are not maintained, excluding livestock and creating conflict. During severe droughts Lake Naivasha is the only water

[5] Growing plants using mineral nutrient solutions, in water, without soil

point for livestock pastoralists. This leads to overgrazing and siltation which reduces future grass supplies. Tourism can also be affected as the lake reduces reducing the RAMSAR species habitats. During droughts the soil is very dry and low pressure develops over the lake increasing the wind strength, which causes erosion, damages crops and can blow off roofs.

Increase in lake and groundwater levels

An increase in river flows, lake levels and the resultant groundwater recharge would be largely positive for Naivasha as there will be more water for domestic and irrigation usage. Evaporation and abstractions are likely to limit significant increases, but the lake would maintain its current levels. The negative impact of this scenario is an increase in the number and intensity of flash floods, increasing the amount of solid waste and silt washed into the lake. The heavy rain can cause the following:

- Latrines collapse (principally due to slabs not being properly sealed) and overflow
- Mud building subside
- Pipes are exposed due to soil erosion
- Water gets in houses
- Wastewater mixes with the flood water
- Crops are damaged
- There is an increase in water borne diseases

Flash floods make road impassable and severely eroded, forming large pot holes and damaging their structure, this is compounded by the heavy rainfall which further degrades the road. This leads to disruption of business, increased transport costs, difficulties transporting food, increases in charcoal prices and children can have trouble getting to school. The advantage of the flood is it clears the streets of solid waste – although it ends up in the lake. The impacts are most severe in Kamere where the land is steepest and there are very fast flows, there are also severe problems in Karigaita; however in both areas the soils are volcanic so the water quickly drains and most homes are unaffected. In Mirera the floods only affect the roads and crops as it is relatively flat and there is more space between houses. During the rains prior to the floods the community is able to harvest rainwater (reducing takings at the kiosks), there is increased employment on local farms and food is cheaper.

The community felt that flash floods are only an inconvenience and not a major threat (although the health clinic observed increases in water borne diseases - diarrhoea, typhoid and amebaebic dysentry) and the benefits associated with the rains outweigh the costs. However; it’s important to recognise that rainfall intensity is predicted to increase, which may increase the severity and frequency of flash floods, making the impacts more severe.

CLIMATE CHANGE AWARENESS

As well as increasing the resilience of water supply and sanitation systems, working with other organizations to build capacity and share knowledge is key for successful adaptation to climate change. Therefore an understanding of the current climate awareness and actions of the different stakeholders is needed. Table 3 gives an assessment of this information based on stakeholder interviews.

Table 4: Climate change awareness and actions of organizations in Naivasha

Stakeholder	Awareness	Plans/Actions	No. Interviews
Community	Limited	None	10
WSUP	Medium	Not assessed in work or in water demand projections in Master Plan	2
NAIVAWASS	Limited	Not assessed in their work	2
Local Council	Medium	No direct plans	2
Farmers	Medium	Not aware of any plans	1
Government	Mixed	- Each ministry must have a climate change focal point - Involved in UNFCCC dialogue - Little regional or district work being completed, seen as issue for central government	7
Research	High	- Studies being undertaken and advocacy work	1
NGOs	High, involved in awareness raising	- WWF completing study looking at the impact of climate change on the catchment	4

Recommendations

Adapting to climate change requires a combination of technological and structural measures, risk sharing and capacity building to increase the robustness of systems. Coping with climate change does not involve many entirely new processes or techniques. It should, however, be made clear that this is not an argument for 'business as usual'. Existing instruments, methods and measures may need to be introduced at a faster pace, and applied in different locations, at different scales, within different socio-economic contexts and in new combinations (CAPNET, 2009). Developing water safety plans should be a priority, to reduce the risks to water supply by establishing a framework for managing the risks to drinking water from catchment to consumer (Bartram 2009).

This section reviews the key adaptations for WSUP (or a subsequent operator, NAIVAWASS and the local Council. The adaptations were determined based on a field visit, a vulnerability assessment and a literature review . Some recommendations will be part of existing maintenance programmes; however, the priority of these actions may need increasing. The adaptations have been divided into three timescales (based on Venton, 2010), four categories and three priorities: high priority, significant threat and actions that will improve resilience of the system. References in brackets provide further information about each recommendation.

- **Short term:** contingency adaptation for extreme events – e.g. Drought management/ flood forecasting, focussed on disaster management experience;
- **Medium term:** tactical adaptations regarding climate variability, linked with disaster risk reduction;
- **Long term:** adaptations necessary to respond to a predicted different climate.

The adaptations categories (based on Charles *et al*., 2010):

- **Capital expenditure**, which includes new investments and projects;
- **Operational expenditure**, which includes adaptations that can be made to existing systems;
- **Monitoring**, which includes programmes that can be implemented immediately to support planning decisions, or implemented in the long term to support continuing decisions;
- **Socioeconomic,** tools such as community education, training and public awareness.

SUMMARY OF ADAPTATIONS IN THE PERI-URBAN AREAS

The main impacts of climate change in the peri-urban areas around Lake Naivasha are a lack of access to affordable water during droughts, flash floods from the upper catchments causing latrines to overflow and heavy rain making latrines unstable. The main adaptations to each of these issues are outlined below:

- **Ensure affordable and accessible water supply:** during droughts there is increased unemployment, and higher living costs. Maintaining cheap water at the kiosks will ensure all households can still afford water and have enough for the increased domestic demand, avoiding a deterioration of hygiene and health and women spending large amounts of time collecting water. In Kamere installing a pump needs to be addressed as soon as possible in the interim there should be community education on source selection and treatment. In Mirera there should be management capacity building of the owners of the borehole system. In addition, water levels should be monitored during droughts and the data given to the WRMA so they can ensure the WAP designations adequately protect domestic supply

- **Continue to Support Catchment Management Plan:** deforestation and poor catchment management impact the peri-urban areas through erosion, high winds and flash floods. The peri-urban areas impact the catchment through their abstractions and solidwaste and wastewater which pollutes the lake. Damage to the lake impacts the flower farms which affects livelihoods. The solidwaste collection should be addressed, latrines promoted and education on open defecation needs to be advocated by WSUP. The direct impact of the peri-urban areas on the catchment is small; but the impacts on the peri-urban areas are significant. WSUP should continue to support WWF and the LNRA catchment management plan when requested (possibly installing drainage and terraces or providing land for afforestation) – the exception is subsidising payments for environmental services through the water tariffs, this should be avoided as it would impact the poorest households.

- **Latrine Construction and Education:** damage to latrines and overflowing sludge present the largest risks from flash floods and although few overflow, it is significant when they do. When building new latrines the soil should be compacted, a good seal installed, bricks used below ground level and 300m above ground rather than mud and the drainage paths accounted for (when necessary face latrine doors down slope). However, the priority should be educating the community on construction methods as WSUP sponsored latrines are of high quality and the main risks are from poorly constructed household latrines (detail on construction: ITDG, 2007)

- **Protecting Boreholes:** Rainfall is predicted to become more intense, so it is important to ensure the well head on the supply boreholes are properly sealed and no water can get into the borehole (e.g. make sure no cracks on the plinth, check cover clean, proximity to latrines, check 1m radius of concrete, put up fence to keep livestock out; WHO 2.1, 1996 and Lloyd and Helmer 1991)

WSUP/ Local Service Provider

Immediate/ Short term (0 – 6 months)

Capital Expenditure

- Ensure proper compaction of soil around the latrine and presence of adequate base and earth filling to protect pits, pit covers and slabs
- Replace pump at borehole in Kamere
- Ensure the use of durable materials in construction of latrines and raise the level

Operation Expenditure

- After flooding assess and address infrastructure damage (Reed, 2006 &WHO, 2003)
- Investigate the source of flash floods (is it from the catchment or local rain)
- Hygiene education on source selection and treatment in Kamere (Appleton and Sijbensema, 2005)
- Pipe maintenance programme to reduce leaks (DOH, 2008, EPD, 2007 & WHO, 2001)
- Regular maintenance of soil around pipes to protect against collapse (WHO, 2003, Chp 7)

Monitoring

- Sanitary inspection of latrines, storage and hygiene (Appleton and Sijbensema, 2005)
- Water use surveys to identify demand
- Carry out regular inspection and vulnerability assessments of kiosks

Social Economic

- Hygiene education on the importance of first flush when rainwater harvesting
- If pipes are exposed to water develop communication procedures to notify the community when the water is safe (Curtis, 2005)

Medium Term (6 Months – 1 year)

Capital Expenditure

- Ensure that well heads are properly designed to prevent erosion damage that may increase infiltration (WHO, 2003)
- Build bunds (banks, dykes or levees) to divert flow away from system
- Education on the need to site latrine away from drainage channel, ensure proper seal when constructing pit latrines and build latrines with doors facing down slope
- All construction below ground from stone/bricks, possibly use properly compacted sand blocks (method in ITDG, 2007)
- After flooding disinfect pipes (WHO 2.27, 1996)
- Develop borehole protection zones, ensure no risk from contaminants (WHO 2.1, 1996)
- Adopt higher design standards for infrastructure to take more frequent extreme weather events into consideration
- Use compaction of soils and planting around infrastructure to increase durability of structures

Operation Expenditure

- Develop Water Safety Plan (Bartram 2010)
- Capacity build management of private borehole operators in operation and distribution in Mirera
- Adapt maintenance programme to identify breakages (DOH, 2008 & (EPD 2007)
- Ensure high levels of maintenance on boreholes to avoid unnecessary losses of water at the point of use
- Plan for emergency supplies of drinking water to be available in the event of system failure
- Provide assistance emptying old latrines (Scott and Reed, 2006)
- Reduce non-revenue water (Parker, 2010)

Monitoring

- Monitor microbial quality of water in boreholes during droughts and floods
- Monitor the water levels in boreholes during droughts
- Monitor water use at kiosks during droughts
- Investigate the development of plot soakaways to reduce household flooding

Social Economic

- Educate communities about reliable water sources: how to select them, what makes them reliable, (Appleton and Sijbensema, 2005)
- Raise awareness among the public of the risk of contamination during and after extreme rainfall events (Reed, 2006)
- Community education/empowerment on need to maintain drains and build basic structures to minimise flooding – e.g trenches with rubble steps (Cairncross *et al.,* 1991 & Parkinson 2010)
- Education on latrine construction: soil compacted, good seal installed, bricks used rather than mud and the drainage paths accounted for
- Educate schools on dangers of mixing the water brought from pupils (in droughts some schools require pupils to bring in water which is then mixed together)
- Disseminate health advisory notices to the public with advice about dealing with the risks in droughts
- Develop and explain benefits of ECOSAN in areas with agricultural use (Smet and Sugden 2006)
- Raise awareness among water engineers of risks from water quality changes during extreme rainfall events, and how to manage the risk
- Raise awareness about risks from water quality changes during flooding and the need for household water treatment

Long Term (1 year+)

- Maintain low price for water
- Assist WWF in catchment management plan
- Investigate methods to increase the artificial recharge of groundwater (BGR, 2009)
- Raise awareness among the community about the damage that erosion can cause to infrastructure, and the potential effect on the water supply system
- Raise awareness among the community about the damage that erosion can cause to wells and boreholes
- Consider deepening boreholes
- Determine the degree of vulnerability through investigating linkages between climate and groundwater, e.g. residence times, recharge rates and water level monitoring

Other Stakeholders

Adaptation to climate change requires an integrated approach from all stakeholders. Alongside WSUP, NAIVAWASS and Naivasha council are central for providing water and sanitation in the peri-urban areas. NAIVAWASS' priority needs to be incorporating the kiosks system into their distribution network, as larger systems are more resistant and better able to adapt to climate vulnerability (Bartram and Howard, 2010). In addition NAIVAWASS should adapt their system to better cope with flash floods, in particular their sewage network and treatment systems. The council have a central role within the catchment management plan. Maintaining, improving and developing new drainage is a key part of their role; combined with terracing and tree planting in the upper catchment. This will reduce flash floods, siltation, erosion and improve the quality of the lake. In addition, It is important that the council work in close collaboration with WRMA when Water Abstraction Plan is updated. The following identifies focused recommendations for NAVIAWASS and Naivasha council, on how they can help support the peri-urban areas in adapting to climate change. The adaptations for both are split into short, medium and long term adaptation and divided by priority (high priority, significant threat and action that will improve resilience of systems).

NAIVAWASS

Short term (0 – 6 months)

- Monitor water quality during droughts and floods
- Carry out regular inspection and vulnerability assessments of structures (WHO 2.1, 1996)

Medium term (6 months – 1 year)

- Build bunds (banks, dykes or levees) to divert flow away from system
- Adopt higher design standards for infrastructure to take more frequent extreme weather events into consideration (WHO, 2003)
- Concentrate water quality monitoring during periods of extended droughts
- Enhanced inspection of infrastructure after flash floods
- After flooding disinfect pipes (WHO 2.27, 1996)
- Monitor water quality and adapt treatment processes to ensure that water quality is not compromised (e.g. increasing sedimentation time and improving filtration systems)
- Install hydrological monitoring stations; rain gauges and access earth observation data
- Introduce additional more robust barriers and treatment stages
- Select appropriate water treatment stages to suit water quality
- Increase attention to construction quality and setting out of sewers, more rodding eyes, steeper falls, consider low-flush toilets (Gate, 2001)

Long term (1 year+)

- Develop emergency water plan for times of extreme scarcity, such as linkages to other sources or emergency tank supplies
- If supply from the borehole is already variable, consider that the current boreholes may need to be extended or new deeper boreholes may need to be installed

Municipality – Naivasha Council

Short term (0 – 6 months)

- Maintain drainage and culverts, ensure clear (Cairncross *et al.,* 1991 & Parkinson 2010)
- Maintain conditions which mitigate erosion e.g. compaction of soils and planting in buffer strips
- Maintain roads to reduce standing water and erosion

Medium term (6 months – 1 year)

- Improve drainage (Reed, 2006 & Parkinson 2010)
- Educate community on need to maintain drains
- Divert water from upper catchment away from town, tree planting
- Develop communication procedures to notify the community when the water is safe
- Improve legislation for allocation of riparian land, ensure wildlife and livestock access, establish processes to address conflict
- Land management – minimize erosion with planting schemes, buffer strips and storm water management
- Work with WRMA to incorporate climate change into work and expand hydrological network of monitoring stations – rain and lake gauges
- Provide assistance emptying old latrines (Scott and Reed, 2006)
- Install basic sand pump at Kamera at lake edge to filter pollutants from Lake (WHO, 2.5, 1996)

Long term (1 year+)

- Expand upstream terraces to reduce runoff
- Afforestation
- Garbage collection
- Provide free meal in schools during droughts to improve attendance
- Investigate methods for the artificial recharge of groundwater/Investigate catchment management practices to promote infiltration (BGR, 2009)
- Work with WRMA to quantify the reserve water levels in lake
- Establish more efficient charcoal production (burning in kilns rather than covering with soil)
- Reward farm forestry

Response to Recommendations

A response to the following questions will be included from WSUP, NAIVAWASS and the Council:

1. How will [stakeholder] respond to the climate proofing recommendations?
    a. How will the adaptations be implemented?
    b. How do they impact long term plans?
2. What additional information do you require to apply the adaptations?

Further Information

Climate modelling and climate change adaptation are both areas of continuing research. It is important to be aware of the ongoing work being undertaken which will inform future investments and adaptations. Table 4 illustrates that although climate change is recognised at the policy level, there is little work being implemented regionally. As policy filters down it will have a greater impact on resource management and it is important to stay aware of changes to policy.

Current Research

- **WWF** are completing a study of the impact of climate change on the Lake Naivasha basin
- **Water Abstraction Plan:** The Water Resource Management Authority will be updating the Water Abstraction Plan and reviewing the new abstraction levels applied to the lake and each river and assessing how climate change is incorporated to revisions will be important

Key Researchers

- **Dr. Robert Becht:** Assistant Professor: Department of Water Resources, ITC, Netherlands. Supervised over 60 MSc projects around Lake Naivasha and one PhD. Focus on modeling the lake: water balance, surface water, groundwater, water management and allocation) www.itc.nl/about_itc/resumes/becht.aspx
- **Dr David Harper**. Senior Lecturer. Department of Biology. University of Leicester, UK. Investigation of sustainable management of water resources and ecology of Lake Naivasha www2.le.ac.uk/departments/biology/people/harper
- **Dr Daniel Olago**: Senior Lecturer in Geology: Department of Geology, University of Nairobi, Kenya. Assessing sustainable management of water resources and assessing climate change vulnerability www.uon.ac.ke/profiles/?id=165900
- **Dr William Shivoga**: Senior Lecturer/ Head of Department of Environmental Science, Egerton University, Kenya. Studied the lithology of Lake Naivasha www.uwyo.edu/SUMAWA/bios/principalinvestigators/shivoga.htm

Climate change donors in Kenya

The following is a list of donor who are known to be supporting climate change adaptation in Kenya. It was noted that at present the Government has not secured much funding allocated for regional environmental and natural resource issues

- Danish Development Agency (DANIDA)
- Heinrich Böll - Foundation
- Christian Aid
- CORD Africa
- Carbon credit Scheme
- Reducing Emission from Deforestation and Forested Degradation (REDD+)
- UNDP
- World Bank

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Appendix

STAKEHOLDER INTERVIEWS

Table 5 Overview of interviews undertaken in Naivasha

Organisation	Number of Interviews
Naivasha Council	**2**
Community	**8**
• Karagita	2
• Kamera	5
• Mirera	1
WSUP	**2**
Government	**7**
• WRMA – Naivasha	2
• Ministry of Agriculture – Naivasha	1
• Fisheries Officer– Naivasha	1
• Health Clinic– Naivasha	1
• Kenyan Meteorological Organisation	1
• National Environmental Management Authority – Naivasha	1
NAIVAWASS	**2**
Farmers	**1**
NGO	**4**
• Lake Naivasha Riparian Associate	1
• Lake Naivasha Grower's Group	1
• WWF	2
Research	**1**
• Institute for Environment and Water	1
Focus Groups	**2**
• Karagita	2
Total	**29**

Impact of climate change on Lake Naivasha

To assess the impact of climate change on Lake Naivasha the data used in the water balance model was modified to evaluate the sensitivity of the lake to changes in surface inflow, evaporation and rainfall and assess how the WAP abstractions would have differed calculated. 20 simulations were completed in total using the following method:

1. Monthly surface inflows were varied[6] by a fixed percentage (between -25% & 25%) and the monthly lake level modelled between 1932 and 2006
2. The value of monthly precipitation was decreased by a fixed percentage (-5%, -10%, -15%, -20%, -25%) and the monthly lake level modelled between 1932 and 2006
3. The value of monthly evaporation was increased by a fixed percentage (5%, 10%, 15%, 20% & 25%) and the monthly lake level modelled between 1932 and 2006
4. The WAP designation was calculated for each month between 1932 and 2006 for the original data
5. The WAP designation for the lake was calculated for each month between 1932 and 2006 for each model simulations
   NOTE: variables were not modified simultaneously

Figure 4 displays the result indicating how the lake level would have changed for each simulation and how on average the lake would have been classified for each scenario (e.g. If the evaporation was 10% higher between 1932-2006 what percentage of months would the lake have been scarce). The method is simplistic and has major limitations (principally the changes won't happen independently, past climate can't be relied on for predicting the future and the change in percentage would vary); however, it gives a rough indication of the significance of changes in runoff, evaporation and rainfall.

The analysis indicates the lake is more sensitive to changes in surface water inflows and evaporation than rainfall. Either a 10% increase in evaporation or a 10% percentage decrease in surface water reduces the lake level by a metre and significantly increases the number of months it is classed as scarce – from 5.2% of months to around 25%. If surface water inflows increase the lake level will increase and be classed 'satisfactory' for most months.

[6] Surface runoff values were both increased and decreased due to uncertainties with infiltration dynamics

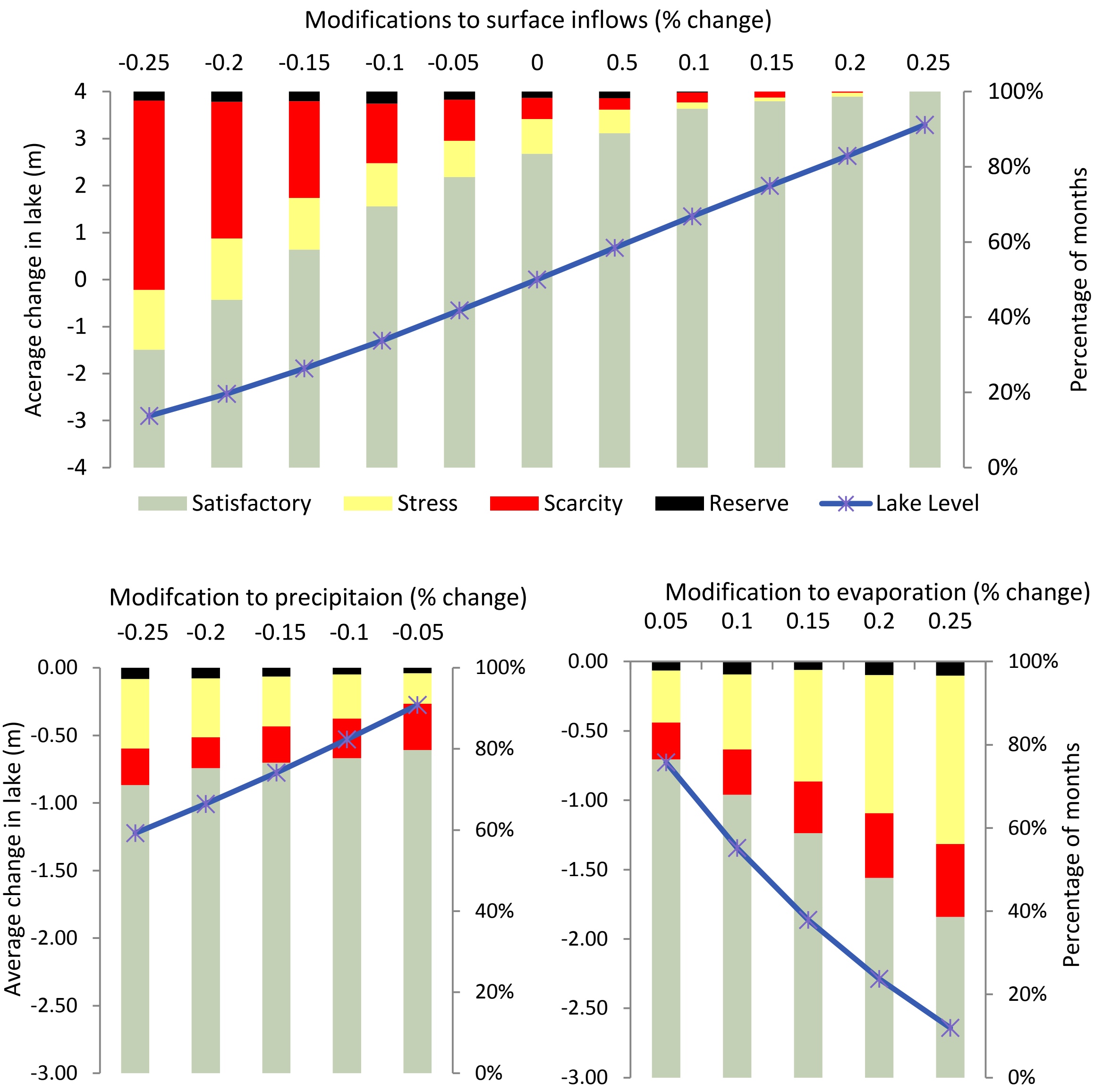


Figure 5: Impact of changing runoff, evaporation and rainfall on Lake Naivasha. The blue line indicates how the average height of lake would have differed if the monthly surface inflow, evaporation or precipitation were varied by a fixed percentage between 1932-2006. The bars indicate percentage of months the lake would have been each designation for each scenario (e.g. If evaporation had been 10% higher between 1932-2006 the lake would have been on average 1.34 m lower and for 25% of months it would have been classed 'Scarce').

This analysis indicates that surface water inflows have a significant effect on lake levels; therefore further studies should clarify how changing land use impacts inflows. Changes in rainfall have half the impact of changes in evaporation with a 10% reduction reducing the lake level by under a meter. Rainfall has less influence on the lake as it inputs half the volume inputted by surface water and removed by evaporation (95 M m^3 compared to 220 M m^3 and 260 M m^3, Table 2). If evaporation increases or surface water decrease coincided with a drought similar to the one of 1940 and current abstractions continue the lake would dry up - the new WAP limits should prevent this, but it highlights the significance of climate change and the need for sustainable management of the lake.

VULNERABILITY ASSESSMENT

Understanding the existing vulnerabilities is central to assessing the impacts of climate change. Figure 4 outline the environmental vulnerabilities and problems with the water supply systems in the peri-urban areas and impact of the climate scenarios predicted for Naivasha. Both scenarios (increasing and decreasing lake and groundwater levels) are represented on the diagram, as there would be overlap. The factors directly impacted are highlighted red and impacted factor in pink –the darker the colour, the greater the likelihood the problem will be affected by climate change, factors that are not affected are green.

Figure 4 Impact of climate change on the peri-urban areas in Lake Naivasha (red indicates direct impact of climate change, green no direct affect, dashed lines are for visual purposes)

LITERATURE REVIEW

In addition to identifying the impacts of climate change on the existing vulnerabilities and problems in the peri-urban areas in Lake Naivasha the literature was reviewed to assess the impact of climate change on water and sanitation technologies. The following tables overview how the technologies (current and planned) are vulnerable to the key issues and the resulting impacts. The tables are based on observations during the field visit and literature, which assesses the impact of climate change on technology – principally a review completed by the WHO and DFID in 2010 (Charles *et al*., 2010).

Impact of Climate Change on Technology in Peri-Urban Areas

Borehole

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Water availability decreases	Insufficient water for demand	Water shortages and potential for water rationing. Public health risk from inappropriate water saving in the home	Investigate alternative and supplementary water sources and water harvesting methods, such as rainwater collection and water reuse. Prioritize water use for drinking. Investigate methods for the artificial recharge of groundwater Investigate catchment management practices to promote infiltration. Consider deepening the wells and boreholes	Ensure high levels of maintenance on wells to avoid unnecessary losses of water at the point of use	Monitor water use at well for user pays scheme, and assist in demand management. Monitor the ability of wells to cope with current droughts	Implement education programme to reduce water demand. Promote the importance of hygiene
	Increased use of viable wells causes increased wear and tear, and increased water demand	Damage to well or borehole increases the risk of contamination entering water source. Public health risk from consumption of the water	Determine the degree of vulnerability through investigating linkages between climate and groundwater, e.g. residence times	Ensure high levels of maintenance on in demand wells	Sanitary survey. Monitor the ability of wells to cope with current droughts	
	Less water available for hygiene and cleaning	Public health risk from inappropriate water saving in the home	Research cleaning and hygiene methods that have low-water usage		Water use surveys	Raise awareness of the importance of hygiene
	Groundwater levels dropping, especially during a dry period or season	Water shortages and potential for water rationing. Public health risk from inappropriate water saving in the home. Increased risk of contamination of the water at the end of the drought	If supply from the well is already variable, consider that the current well may need to be extended or new deeper wells may need to be installed. Install relief wells that can be uncapped for easy use in dry periods to supplement existing wells	Determine the degree of vulnerability	Concentrate water quality monitoring during periods of high risk at the end of the droughts	
Run-off increases	Erosion	Permanent loss of borehole or well. Damage to the structure of the borehole or well, leading to a temporary loss of supply. Public health risk from contaminants entering the standpipe	Ensure that well heads are properly designed to prevent erosion damage that may increase infiltration. Use compaction of soils and planting around infrastructure to increase durability of structures	Maintain conditions which mitigate erosion e.g. compaction of soils and plants in buffer strips.	Monitor microbial quality of water after the well or borehole has been renovated	Raise awareness among the community about the damage that erosion can cause to wells and boreholes. Develop communication procedures to notify the community when the water is safe
Increase in extreme rainfall events	none					

COMMUNITY-MANAGED DRINKING WATER SYSTEMS (DIRECT CONNECTIONS)

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Water availability decreases	Insufficient water for demand, or increased seasonality of water	Water shortages and potential for water rationing. Public health risk from inappropriate water saving in the home	Restrict water supplies and switch pipes off. Investigate alternative water sources and water harvesting methods. Develop emergency water plan for times of extreme scarcity, such as linkages to other sources or emergency tank supplies. Integration of systems may protect from water shortages	Pipe maintenance programme to reduce leaks. Prioritize allocation for domestic use. Establish centralized support unit to provide technical and administrative assistance	Monitor for microbial quality of water.	Educate communities about reliable water sources: how to select them, what makes them reliable, etc. Promote the importance of hygiene. Implement education programme to reduce water demand.
Run-off increases	Increased erosion leading to more polluted run-off, with silt and nutrients.	Increased suspended sediment loads may exceed the treatment capacity of the water treatment facilities. Public health risk from contaminants entering the water distribution system.	Land management – minimize erosion with planting schemes, buffer strips and storm water management.	Maintain vegetation in buffer strips next to rivers. Establish centralized support unit to provide technical and administrative assistance.	Monitor water quality and adapt treatment processes to ensure that water quality is not compromised, such as by increasing sedimentation time and improving filtration systems.	Raise awareness among the community of the risk of contamination during and after extreme rainfall events. Disseminate health advisory notices to the public with advice about dealing with the risks. Develop communication procedures to notify the community when the water is safe.
Increase in extreme rainfall events	Damage to infrastructure	Potential failure of the drinking-water supply system and loss of service. Public health risk from contaminants entering the water distribution system through damaged pipes.	Adopt higher design standards for infrastructure to take more frequent extreme weather events into consideration.	Response plan after flooding to assess and address infrastructure damage. Plan for emergency supplies of drinking water to be available in the event of system failure.	Hydrological monitoring stations. Rain gauging. Earth observation data. Enhanced inspection of infrastructure.	Raise awareness among the public of the risk of contamination during and after extreme rainfall events. Raise awareness among water engineers of risks from water quality changes during extreme rainfall events, and how to manage the risk. Disseminate health advisory notices to the public with advice about dealing with the risks.
	Surface water quality deterioration during floods.	Floodwater carries increase sediment load that may exceed the treatment capacity of any small-scale water treatment system that is part of the supply system. Run off water from upstream may carry higher concentrations of chemical and microbial contaminants. Risk to public health from consuming the water.	Adapt water treatment for flood conditions depending on water source and contamination. Introduce additional more robust barriers and treatment stages. Relocate abstraction points, where possible.	Select appropriate water treatment stages to suit water quality. Dig out buried intakes after the flood waters recede.	Sanitary inspection. Simple monitoring of raw water quality, e.g. turbidity.	Develop communication procedures for when water is safe. Raise awareness about risks from water quality changes during flooding and the need for household water treatment.
	Flooding causes damage to bridges that support mains or distribution pipes over rivers.	Localized or widespread disruption to water supplies.	Review risks and benefits of burying main under river or supporting from bridge over the river. Select least risk option. Install isolation valves at both sides of crossing.		Carry out regular inspection and vulnerability assessment of structures.	Develop monitoring, management and communication procedures with the bridge owners, if not owned by the community

Kiosk/ Standpipe

Issue	**Vulnerability**	**Impacts**	**Adaptations**			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Water availability decreases	Addressed in community managed supply					
Run-off increases	Erosion damaging standpipe.	Destruction of the standpipe and loss of service. Public health risk from contaminants entering the standpipe	Land management – minimize erosion with planting schemes, buffer strips and storm water management. Use durable materials in construction	Maintain conditions which mitigate erosion, e.g. compaction of soils and plants in buffer strips.	Sanitary survey.	Raise awareness among the community about the damage that erosion can cause to infrastructure, and the potential effect on the water supply system Disseminate health advisory notices to the public with advice about dealing with the risks.
Increase in extreme rainfall events	None					

IMPROVED PIT LATRINES

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Increase in extreme rainfall events; run-off increases	Erosion	Collapse of latrine	Site latrine away from drainage channel. Use durable materials in construction to protect pit covers. Proper compaction of soil around the latrine and presence of adequate base and earth filling to protect pits, pit covers and slabs. Install robust upper foundations, collar and footing to protect from erosion and flooding	Regular maintenance essential to limit vulnerability to collapse		Hygiene promotion. Education on regular maintenance requirements
Water availability decreases	Increased distance to GW tables	Reduced risk of groundwater pollution	Pit latrines become more viable option			

FUTURE: SEPTIC TANKS

Issue	Vulnerability	Impacts	Adaptations	Issue	Vulnerability	Impacts
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Increase in extreme rainfall events; run-off increases	Erosion of soil around the tank and absorption field	Damage to infrastructure. Reduced efficacy of the absorption field	Planting of grasses and shrubs on the absorption area, and around the tank, to reduce erosion. Repair erosion damage and sod or reseed areas as necessary to provide turf grass cover. Build bunds (banks, dykes or levees) to divert flow away from system	Check the vegetation over the septic tank and soil absorption field after flooding.		
Water availability decreases	Less water available for flushing and cleaning	Toilet and discharge pipe becomes dirty or blocked	Examine lower-water use approaches (plastic seals rather than water seals, for example) and slabs that are easier to clean. Increase attention to construction quality and setting out of sewers. More rodding eyes. Steeper falls. Consider low-flush toilets. If no water available, septic tanks will not be a viable option. Investigate other systems for management of human excreta	Consider feasibility of households doing more regular cleaning, rodding etc. Improve solid waste management, especially for fat solids	Septic tank system inspections	Education and awareness of lower-water use latrine options
		Reduced risk of groundwater pollution	Septic tanks become more viable option			
	Changing moisture levels in soils	Movement and infrastructure damage	Design for movement.	Adapt maintenance programme to identify breakages	Monitor performance for blockages and breaks	

Appendix F: Madagascar Climate Brief

MADAGASCAR CLIMATE CHANGE BRIEFING

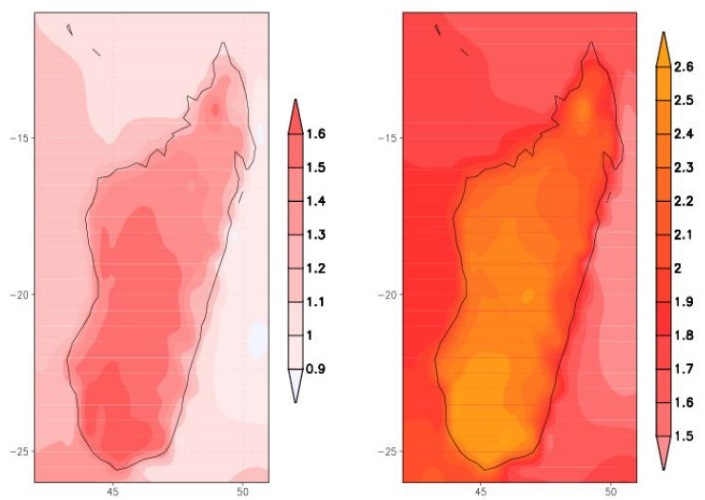
Overview

Madagascar's climate and terrain is highly varied- the South West is semi-arid while the East coast is tropical and humid. The average temperature varies between 23-27°C in the coastal areas and 16-19°C in the upland plateaux, the annual variation being around 3°C in the North and 7.5°C in the South West region. The rainfall varies from 3700 mm in the East (hot and humid) to 400 mm in the West and South West (hot and semi arid). The Highlands, the Western region and the South have two very distinct seasons - the rainy season from November to April and the dry season from May to October - while in the Eastern region it rains practically all year round and a dry season is hardly perceptible. Rainfall on the East coast is driven by the Easterly trade winds meeting the uplands, while rain in the central uplands and West is mainly due to convective activity and thunderstorms linked to the Inter-Tropical Convergence. The North and North East are affected by tropical cyclones (forming over warm waters in the South Indian Ocean) and floods, resulting in heavy rain and strong winds (the cyclone season is November to May).

Climate Change

Observational evidence from all continents and most oceans shows that many natural systems are being affected by climate change, particularly by temperature increases. The minimum temperature in Madagascar has been consistently increasing. In the South, temperatures have been steadily increasing since the 1950s (0.2°C warmer in 2000) and drought has become more frequent; in the North temperatures have started rising, but they were 0.1°C cooler in 2000 than temperatures at the beginning of the century. There has been a lower volume of rainfall but it is unclear if it is influenced by global warming, or by micro-climate changes arising from the loss of 80%-90% of forest cover in Madagascar over the last century.

The temperature changes in Madagascar were predicted using a regional climate model based on 13 global climate models (GCM) for the period 2046-2065. The model shows warming across the island and areas of both increasing and decreasing precipitation. Southern Madagascar is projected to have the greatest warming (2.6°C by 2055), while less warming is predicted in the coastal areas and the North (1.1°C). Figure 1 displays the maximum and minimum temperature changes predicted for Madagascar.



Changes in precipitation were predicted based on 6 downscaled GCMs assessing the medium value of change in precipitation for 6 emissions scenarios (the scenarios describe different economic growth and energy usage patterns) for 23 weather stations. The models project median rainfall will increase throughout the summer months (November to April). During the winter (May – October) the tropical regions are predicted to be wetter, and have more frequent storms, while the Southern half of the East coast is projected to be drier by 2050. This is significant as the South is the driest part of the country and the forests in the East are highly fragmented and vulnerable to reduced rainfall. Rainfall intensity is predicted to increase during the rainy season but decrease in the dry season. Models predicted that the likelihood of cyclones forming will decrease during the early part of the main season, but that their intensity, associated winds and destructive power are suspected to increase.

Temperature

The mean temperature is predicted to increase in Madagascar. The largest increase will be in the south, while the coastal areas and north will experience less warming

Rainfall

In the tropical regions rainfall is predicted to increase and be more intense, and there will be more frequent storms; in the East and South rainfall is expected to decrease

Extreme Events

Cyclones will occur less often but be more intense, there will be more floods in the North and more droughts in the South and on the East Coast

Cranfield UNIVERSITY

WSUP Water & Sanitation for the Urban Poor

MAIN IMPACTS OF CLIMATE CHANGE

Madagascar has severe problems with soil erosion and deforestation, which reduces soil fertility and productivity, increasing the vulnerability of agriculture and fishing-based livelihoods (livestock and fish forms 95% of national dietary requirements and 75% of exchange earnings (NAPA, 2007)). Climate change will exacerbate soil erosion and deforestation and ultimately lead to a reduction in food security, income, water quality and supply. Livelihood options will be reduced, leading to livelihood conversion or migration, which will be compounded by population pressures (USAID, 2008). Migration will typically be to urban areas, where the migrants are often more rather than less vulnerable to certain climate-related impacts. The increased populations in urban areas will increase competition over natural resources and the likelihood of conflict. In addition, resource scarcity can lead to increased capture of resources by elites exacerbating existing inequalities. The table below summarises the main impacts of climate change.

	Increased Temperature	Floods	Droughts	Cyclones
Water	• Less water for agriculture (insufficient water to improve rice farming techniques in the South) • Disappearance of some water points • Swamps and rivers drain in dry season	• Contamination of drinking water • Ingress of groundwater into pipes	• Water shortages and rivers dry up in the South • No water for irrigation or livestock • Deteriorating water quality[1] • Antananarivo plains will not have sufficient water to meet demand in 2050-2100	• Degrade water resources • Flooding
Livelihoods	• Cropping seasons no longer routine[1,3] • Reduction in soil fertility • Decrease in rice paddy productivity[4] and less income	• Soil erosion[5] • Decrease in soil cover and fertility in highlands (soil moved downstream) • No access to schools • Crop damage/loss, leading to food scarcity and hunger	• Famine • Locust swarms • Crop failure e.g. lower rice production (also caused by decreased rainfall) • Disruption of agricultural calendar[2] • Decrease in plants available for handicrafts • Increased vulnerability to fires[6]	• Increased soil erosion[4] • Flooding of crops and damage to plantations • Injured livestock • Crop failure • Sedimentation • Decreased revenue from crops if production is reduced • Disrupted education and jobs
Health	• Food shortages[7] • Malaria risk extends over whole country[8] • Other disease risk zones extend	• Cholera epidemics • Loss of life • Increase in water borne diseases	• Loss of life • Water borne diseases increasing • Less water for hygiene and cleaning	• Increased risk of epidemics • Loss of life • Damage to shelter
Biodiversity	• Loss of habitat[9] • Loss of endemic species[10] • Increase in vulnerability • Reduction of forest areas of all types	• Damage to biodiversity and habitat	• Forest loss aggravated	• Biodiversity destroyed

[1] Compounded by erratic rainfall in the North
[2] The structure of the seasons has been changed by climate change and farmers can no longer rely on the wisdom of their ancestors (cultural calendars)
[3] Most farms are inefficient and need to acquire new land each year to grow the same quantity of food, aggravating land pressures
[4] Productivity per rice paddy has decreased from 0.5 – 1.2 tonnes per capita in 1975 to 0.6 tonnes per capita in 1999 (NAPA, 2007)
[5] Splash and wind erosion of soils leads to the loss of around 7-67 tonnes per ha per year in woodland and 14-114 in the burned forest (resulting from slash and burn), while natural forest only lose 1.5-3 tonnes per ha per year (NAPA, 2007)
[6] Slash and burn and deforestation is succeeded by secondary grassland which is more prone to fires
[7] There has been an observable increase in food insecurity and malnutrition in recent years resulting from the warming in the country (USAID, 2008)
[8] Malaria is endemic in the coastal areas but does not affect the uplands; an increase in temperatures will extend its range
[9] Deforestation has claimed 90% of the island's natural forest, the remainder is highly fragmented reducing wildlife corridors and making it difficult for species to migrate to new areas. If range migrations (movement of species) is possible, Madagascar will lose 11-27% of its habitat; if they are not, it will lose 15-50% (Hannah *et al.,* 2008)
[10] Species that specialise in specific habitats are expected to do particularly badly due to reductions in their habitats

Water Resources

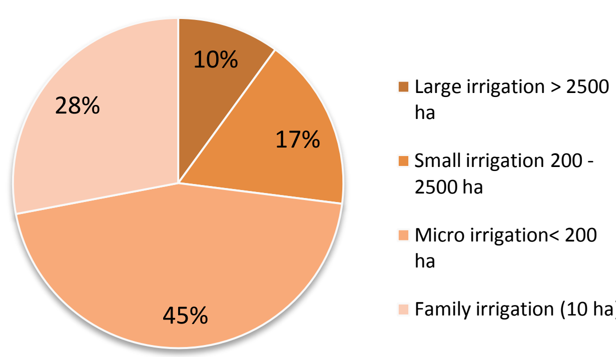
The following overviews the water resources in Madagascar based on the AQUASTAT database (2010) and Madagascar country profile (2005) (developed by the Food and Agricultural Organisation of the United Nations (FAO) Land and Water division). The renewable water resources (those that after exploitation will return to natural levels) in Madagascar are estimated at 337 km^{3}year^{-1} equivalent to 17,600 m^3 per person; however, despite the extensive water resources there is unequal distribution and there are shortages and droughts in the East and South of Madagascar. The main rivers drain 57% of the country and the 13 largest abstractions have a total capacity of 493 million m^3(108 million m^3 for irrigation and 385 million m^3 for hydroelectric). The vast majority of water is used for irrigation (95.6%), with a much smaller proportion for domestic consumption (2.8%) and industry (1.6%). The table opposite summarises the water resources in the country.

AQUASTAT (2010) WATER Resources	Date	Value	Unit
Water Resources			
Long-term average annual precipitation		888.2	km^3/year
Long-term average annual renewable water resources			
Internal		337	km^3/year
Surface Water		332	
Total Dam Capacity	2002	0.493	km^3
Ground Water		55	km^3/year
External		0	km^3/year
Total		337	km^3/year
Total renewable water resources per capita	2008	17634	m^3/year
Water Withdrawn			
Agricultural	2000	14.31	km^3
Municipal	2000	0.42	km^3
Industrial	2000	0.23	km^3
Total water withdrawal per capita	2002	9.24	m^3
By source			
Surface water withdrawal	2000	14.95	km^3
Groundwater withdrawal	2001	0.025	km^3
Pressure on water resources			
Total freshwater withdrawal as percentage of actual renewable water resources	2002	4.439	%
Agricultural water withdrawal as percentage of actual renewable water resources	2002	4.246	%

Irrigation

Irrigation generally uses surface water due to the higher cost of abstracting groundwater; the majority is gravity fed (0.6% is pumped) and used for micro irrigation (<200 ha) and family plots (<10 ha) (Figure 2). Family plots are characterised by rudimentary buildings, simple earthworks and simple bleeds from canals; they are not protected from flooding and need repairing at the beginning of each season (a lot are abandoned due to silting and flooding). Irrigation is mainly used for growing rice (98% of irrigated land), the staple crop of the population (114-145 kg /year per capita 2005). The government is currently trying to rehabilitate existing irrigation structures, but the capacity of the state to maintain large structures is still limited. Environmental damage (deforestation, bush fires) are also major constraints to the sustainability of irrigated areas. In recent years, rehabilitation of infrastructure has been expanded to include elements related to aquaculture, livestock, horticulture and improving hygiene in rural areas.

Figure 2: Distirbution of Irrigated Land (Total 1.1M ha)



Drinking water and sanitation

In Madagascar the utility JIRAMA provides most of the water supply and electricity. In 2005, the National Programme for Safe Water Supply and Sanitation was adopted, with the objective of meeting the Millennium Development Goals. This is now linked with the national budget for medium term water supply and sanitation improvement and increasing sector capacity. A WASH program was put in place in 2002 and a Sanitation Policy was developed in 2006. It is estimated that only about 20% of the population has access to piped sewerage or septic tanks – the remainder rely on on-site sanitation. The reform program is underway and over 50% of the population has access to safe water in the JIRAMA-served areas and 41% of the population has access nationwide (USAID, 2006).The table below summarises the improvements to water and sanitation in urban and rural Madagascar (Joint Monitoring Programme, WHO & UNICEF 2010).

Year	Urban Population (millions)	Rural Population (millions)	Improved Water Supply (%)			Improved Sanitation (%)		
			Urban population	Rural population	Total	Urban population	Rural population	Total
1990	2.6	8.6	78	16	31	14	6	8
1995	3.3	9.7	76	20	34	14	7	9
2000	4.1	11.1	73	24	37	15	8	10
2005	5.0	12.5	71	27	40	15	9	11
2008	5.6	13.4	71	29	41	15	10	11

Vulnerability Assessment

A range of global and regional studies have assessed Madagascar's vulnerability to climate change using global datasets[1,2,3,4,5] producing indices for each country to enable simple comparison. The table below presents the scores (measure of vulnerability) for Madagascar for 9 global indices. The indices which assess the impact of climate change on water resources indicate that Madagascar has a low vulnerability. This is due to Madagascar's relative abundance of water resources; however, this does not account for the regional variations and arid climate in the south. Madagascar has a reasonably low social vulnerability indicating that the government and economy are reasonably able to adapt to climate change. The CVI is an exception indicating that Madagascar has a medium vulnerability to climate change, probably because the CVI also assess geographic factors (such as seas level rise) that relate specific to the location.

Index	Score	Vulnerability	How it's calculated
Water Resources			
Water Scarcity Index (2004)[1]	0.0114	Very low (Abundant)	Water extracted from rivers divided by the low flow (flow exceeded 90% of the time). E.g. If ≥ 1 then consumption exceeds supply
Ground Water Dependence (2004)[1]	0.0013	Very low (Abundant)	Ground water withdrawn as a fraction of total water withdrawn in region
Total freshwater withdrawal as percentage of total renewable freshwater resources (2009)[2]	4.4%	Low	Total freshwater withdrawn in a given year, expressed in percentage of the total actual renewable water resources. It is an indication of the pressure on the renewable freshwater resources (data from 1998-2002)
Annual Renewable Water Supply (Projections for 2025)[2]	17,000 m^3pp	Abundant	Runoff (data from 1950-2000) divided by Population (2025) (prediction from UN population division)
Social Vulnerability (1st = lowest vulnerability)			
Human Vulnerability A (2007)[3]	0.691	4th /49 (Africa)	Social vulnerability to climate change (the Index consists of 5 weighted factors, each of which is scored). HVA includes: economic well being and stability (20%), demographic structure (20%), global interconnectivity (10%) and dependence on natural resources (10%); HVB also includes institutional stability and infrastructure (i.e. corruption (40%))
Human Vulnerability B (includes corruption) (2007)[3]	0.697	1st / 49 (Africa)	
Sensitivity and Adaptability (2007)[4]	0.543	145th / 182 (global)	Human Development Index (used as generic indicator for adaptive capacity)
Sensitivity Index (2004)[1]	2.33	Low	Combination of Water Scarcity Index, GW Dependence and Sensitivity and Adaptability Index
Climate Vulnerability Index (2007)[5]	-	Medium High	The index links water resources modelling with human vulnerability assessments to contribute to a meaningful assessment for generic use

[1] Petra Döll (2009) Vulnerability to the impact of climate change on renewable groundwater resources: a global-scale assessment. *Environmental Res. Letters* 4 (3)
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Appendix G: Madagascar Climate Proofing

How to Climate Proof Water & Sanitation Services in Informal & Peri-Urban Areas in Antananarivo

WSUP
Water & Sanitation for the Urban Poor

Cranfield UNIVERSITY

How to Climate Proof Water and Sanitation Services in Informal and Peri-Urban Areas in Antananarivo

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Work based on field visit to Antananarivo undertaken in August – September 2010

Cover Photo: Alison Parker 2010

Disclaimer
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Reference
Heath, T., Parker, A., & Weatherhead, E. K. (2010). How to Climate proof water and sanitation services in informal and peri-urban areas in Antananarivo. Report prepared by Cranfield University. WSUP, London.

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Executive Summary

This report evaluates the impacts of climate change on water and sanitation technologies in the informal and peri-urban areas in Antananarivo and considers the potential adaptations required to mitigate the impacts. The vulnerabilities and adaptations were determined based upon a field visit, a vulnerability assessment and a literature review. Under current forecasts for Antananarivo mean temperatures, rainfall and rainfall intensity are predicted to increase. There will be more frequent storms and cyclones will decrease in frequency but increase in intensity. This is likely to increase the volume of runoff, raise river levels and increase the speed the river rises; resulting in an increase in flooding from both the river and the drains. The impacts of this scenario are the following:

- **Informal Areas:** there will be an increase in the frequency and severity of flooding from the drains. This presents major health risks and disrupts the lives of communities. Water will get into houses, employment will decrease, it will be more difficult to travel, food costs will increase and the environment becomes dirty, odorous and very unpleasant. The infrastructure installed by CARE, WSUP and WaterAid is resilient to flooding, but the water supplied by JIRAMA is contaminated during floods as the catchment isn't protected, increased run-off leads to soil erosion giving the water a high sediment load and there is high non revenue water (leaky pipes). In addition, household latrines overflow, their superstructures and pits collapse, flying toilets increase (as latrines are flooded), there are long queues at kiosks, taps are submerged and the water pressure is lower.

- **Peri-Urban Areas:** In the uplands they will experience an increase in surface runoff, while the lowlands and paddies will flood from the drains. Areas near the river will also flood. The impacts are similar to the informal areas but there will also be damage to crops and livestock, whilst opportunities for alternative employment will decrease. However, in the per-urban areas there is typically more space to implement local coping mechanisms. When paddies flood the water will take longer to drain

In Antananarivo there have been a number of studies on the impacts of the river and drains flooding. This study focuses upon how climate will exacerbate these risks. However, as there is already an awareness of the environmental risks, there is a good understanding of the required adaptations, detailed in the WSUP SOMEAH *Outline Sanitation Strategic Plan*. In this report this plan has been climate proofed highlighting the need to prioritise Sewage and Stormwater management. As flooding is the primary issue in the peri-urban and informal areas and it will exacerbate other problems. In addition, recommendations were produced for the 40 areas vulnerable to flooding. For these areas potential short, medium and long term adaptations are identified for WSUP (and the local providers), JIRAMA and the Communes. The key recommendations are as follows:

WSUP

- Monitor water from kiosks during floods
- Ensure septic tanks and solid water collection points are flood proof and
- Educate on risks of flooding

JIRAMA

- Commence programme of leak detection and pipe maintenance
- Reduce illegal connections and improve the hydrostatic pressure
- Introduce a new water treatment stage to deal with high sediment load in floods (extra settling tank or more flocculent)

COMMUNE

- Clear and maintain drains and enforce dumping legislation
- Improve solid waste collection and sanitary options

- Minimise occupation of areas not designed for habitation on the city plan

Contents

Introduction

"Observational evidence from all continents and most oceans shows that many natural systems are being affected by climate change, particularly temperature increases" (IPCC, 2007). This report outlines the impacts (both direct and indirect) associated with the climate changes predicted for Antananarivo. It focuses on the informal parts of the central urban area (Urban Commune of Antananarivo – CUA) and the peri-urban areas (OPCI FIFTAMA).

The report starts by reviewing the water resources in Antananarivo and the causes of flooding from rivers and drains. It then summarises the predicted changes to temperature, precipitation and cyclones in Antananarivo and reviews the indirect impacts of climate change. It then synthesises how the climate scenarios will affect water resources and the existing vulnerabilities, problems and technologies in the informal and peri-urban areas of Antananarivo and outlines which activities of the *Outline Sanitation Strategic Plan* (Phase II) will be affected by climate change and how they should be adapted. It then presents the main adaptations required in areas affected by flooding for WSUP, JIRAMA, and the commune, dividing them between short, medium and long-term adaptations. Key climate studies for Antananarivo are also listed.

The report aims to provide pragmatic recommendations for adaptation; focusing upon what is known rather than the uncertainties. The environmental problems affecting Antananarivo (principally flooding) are well documented and the reports should be read alongside this study, which frames the environmental risks within the context of climate change. It should be noted that there is currently a political and economic crisis in Madagascar and because of this there is very limited funding from the government, donors are reluctant to invest and NGOs work with governments is restricted to government technicians.

Method

The research started by identifying literature on the impacts of climate change on water and sanitation technologies. The key document was a review completed by the WHO and DFID in 2010 (Charles *et al*., 2010). This describes the vulnerabilities of various water and sanitation technologies to climate change, and proposes adaptations. This was followed by a field visit which identified the technologies being used in Antananarivo and hence identifying the vulnerabilities of the whole water and sanitation system to climate change. The adaptations required to mitigate these vulnerabilities were selected from Charles et al (2010) and are listed in the appendix.

The field visit to Antananarivo was completed in August 2010 and entailed 22 semi-structured interviews with representatives from the local service provider, water utility, local Council, regional government, scientific community and NGOs (Table 3 in the appendix lists the interviewees). The interviews and observations assessed the impact of flooding and cyclones on the existing environmental, social and economic vulnerabilities and on technologies. The interviews also assessed the institutional awareness of climate risks. Further climate vulnerabilities were identified from the literature review. Eight focus groups were undertaken with the community, completing a cause and effect analysis (i.e. what are the problems, what causes them and what impacts do they have).

The information gathered from the interviews was used to prepare a vulnerability assessment. This involved listing the problems identified in the peri-urban and informal areas and identifying the linkages between them in a flow chart (e.g. floods lead to latrines overflowing). Once the linkages between all of the problems had been identified, the expected changes in climate were added (e.g. increasing rainfall) and the factors they impacted (directly and indirectly) were identified. In addition, the indirect impacts of climate change (e.g. food insecurity) were incorporated assessing which factors they affected. This made it possible to assess how climate change will affect the existing vulnerabilities in the peri-urban and informal areas. This diagram was then used to determine the adaptations required to mitigate the problems. The adaptations from both the fieldwork and the literature review were then amalgamated and assigned to the WSUP, JIRAMA and the local Council, dividing them into short, medium and long term adaptations.

Water Resources and Flooding

This section overviews the water resources in the city and the causes of flooding from the river and the drainage canals. The city is supplied from the Ikopa River, whose flow is controlled by the Tsiazompaniry dam (50 km upstream). The river is diverted to a lake within the city, where the water supply is abstracted by JIRAMA, the water utility. The lake is silting up and though a protection area with a radius of 2.5 km has been designated by ANDEA (2010), it is not enforced. The river has more than sufficient water for drinking (estimated 20 year low flow is 18.1 m^3/s but demand is only 3.1 m^3/s (JIRAMA, 2002)) but during low flows there can be insufficient water for irrigation by downstream users.

Despite the adequate supply there are still water shortages in the city; the shortages are due to:

- The complexity of the system- the city consists of multiple hills and relies on a series of booster stations)
- The age of the system - it was designed 30 years ago
- the 38% non-revenue water (JIRAMA, 2002) - during the rainy season there are many pipes bursts, allowing ingress of contaminates

Leakage is one of the main challenges facing JIRAMA and there are plans to replace all of the old pipes and connections. To compensate for the water shortages, JIRAMA plan to develop groundwater sources. The EIB (European Investment Bank) were funding a new borehole to supply 60,000m^3/day (one third of current production) but this has been suspended due to the political crisis.

The causes of river flooding in Antananarivo were assessed by GTZ (2008), who evaluated the geomorphology, hydrology, climatology, vegetation, and hydrogeology of the plain; the following is a brief summary. Antananarivo is in the highlands of Madagascar, which consist of a raised zone, lateric hills (rich in iron and aluminum) and low lying alluvium areas. The upper basin receives 1250 mm/year of rainfall, slightly higher in the south and south east, where the Ikopa and Sisaony have their sources. The River Ikopa's catchment is predominately bare soil (due to deforestation), heavily exposed to weathering with high rates of erosion of the clay soil and runoff due to low infiltration rates. This leads to a high sediment load, which raises the river bed and causes it to migrate, increasing the levee maintenance requirements. The flood protection is designed so that the peri-urban areas have protection from floods with a 10 year frequency, while the central area has protection against floods that occur once every 100 years (1% chance in any year). However, the reality is there is flooding if rain falls in the catchment at a rate of 30 mm for one hour, which is often exceeded if there are cyclones. The factors contributing to flooding in the CUA and Peri-urban areas are:

CUA:

- The drainage channels are ineffective (Box 1)
- High groundwater tables in the low lying peri urban areas during rainy season
- The drains have to be pumped when the river is high after rains when their full
- Many of the informal areas are lower than the drains. These areas were not designed for habitation; here the flood waters should drain into the clay soil
- The renovation of the roads in 2000, as prior to this the roads drained the areas, but now they have been raised so now they trap the flood water

Peri-Urban Area:

- The river is constrained (rocky for about 7km) at the confluence with three other rivers (Figure 1) This limits river flow and reduces the speed the river levels drop after rain events (SOMEAH, 2010c)
- Clay soils cause high rates of runoff from the hills
- The flood protection levee is too low or has not been maintained

The extent of the flooding was modelled by SOMEAH (2010c) using a digital elevation model with a horizontal resolution of 30 m (Figure 2). The modelling was undertaken using CARIMA a model developed by SOGREAH, which models the flow in the river and links it to the flood plain (Details in SOMEAH, 2010c). They have also modelled the 20 year and 50 year flood and will be modelling the 1 in 100 and 1 in 10. Based on this work they identified 5 areas with critical drainage covering 40 fokontanys (local administrative districts) (Figure 4).

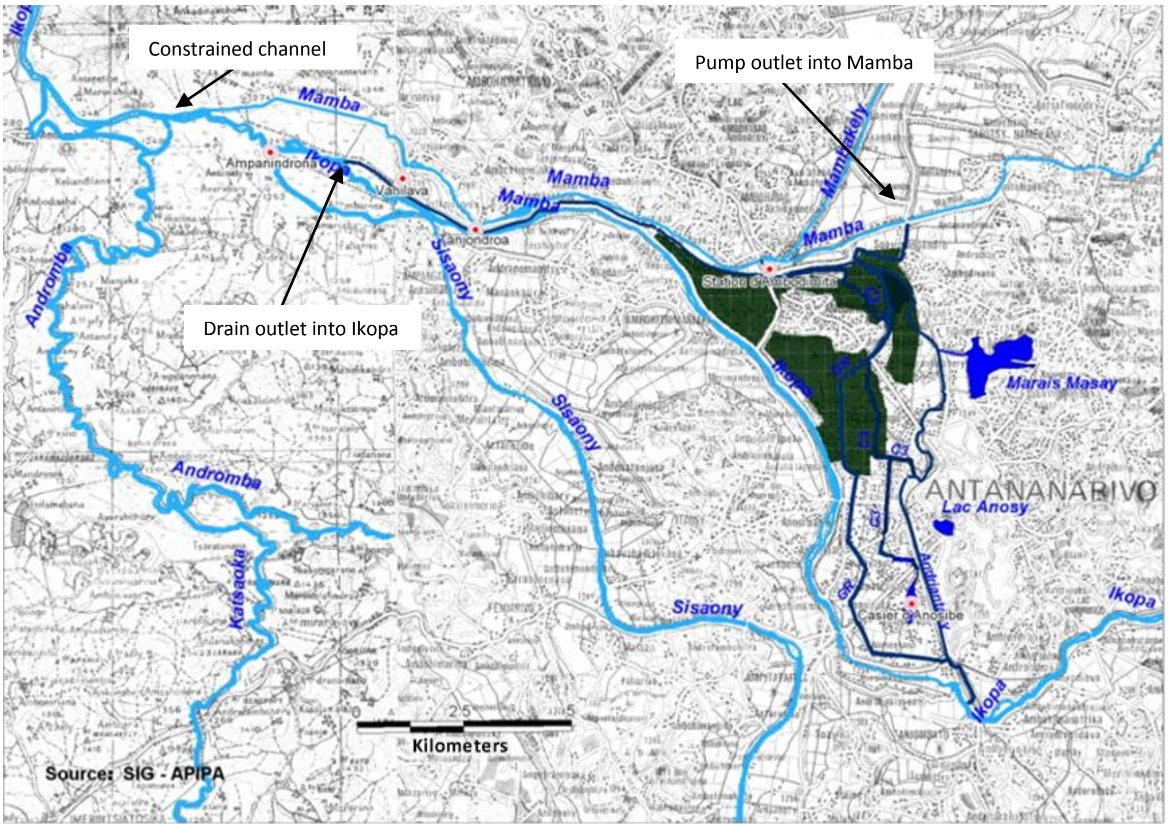

Figure 1 The rivers and drains of the Antananarivo plain (APIPA cited in Drecher *et al.,* 2008)

Box 1: Drains of Antanarivo

Antananarivo has significant problems with flooding from its drainage canals. The primary drains in the city are ineffective and regularly block as they only have a gradient of 2 m in 10 km (0.002), are filled with garbage and sewage and are not properly maintained. The main channel (Andriantany) is 25 km long, has been dug into the plain (depth of 90 cm) and drains the hilly part of the city. The central C3 drain is 10 km long and drains the urbanized area of the plain, providing both the transfer of sewage from urban areas and drainage of the upstream rice plots. There are also two buffer lakes that absorb storm flows the channels cannot absorb immediacy. When river levels are low it is possible for these canals to drain under gravity into the river Ikopa. However when the river level is high and gravity drainage is not possible, a pumping station in the north (Ambodimita) is activated. This involves closing the storm flaps and pumping the water upstream into the Mamba using 3 pumps, each pumping 3 m^3s^{-1} (APIPA, 2006). There are also secondary and tertiary drains, which are managed by the community and fokontanys.

APIPA have monitored the river and rainfall since 2000. Figure displays the record for Bevomange station, which is located at the outlet of the plain where the drains discharge. If the water level is above 1247 NGN the drains must be pumped to the Mamba. During this time the storm water cannot drain from the city. Figure displays the river level for three gauging stations on the Ikopa between 2006 and 2007. If the water levels is above 1248.6 NGN in the Mamba the pumps cannot be used, to avoid rupture of the right bank of Mamba appafarm dam. The 2007 event is the largest on record and corresponds to a 1 in 5 year floods (Drescher *et al.,* 2008). The flooding was caused by the largest rainfall event on record which had a return period between 10 and 25 years (Drescher *et al.,* 2008). During this period the level of the River Mamba prevented pumping for 38 days (between 16/01/07 and 26/02/07) during which time the drainage in the city would have been limited.

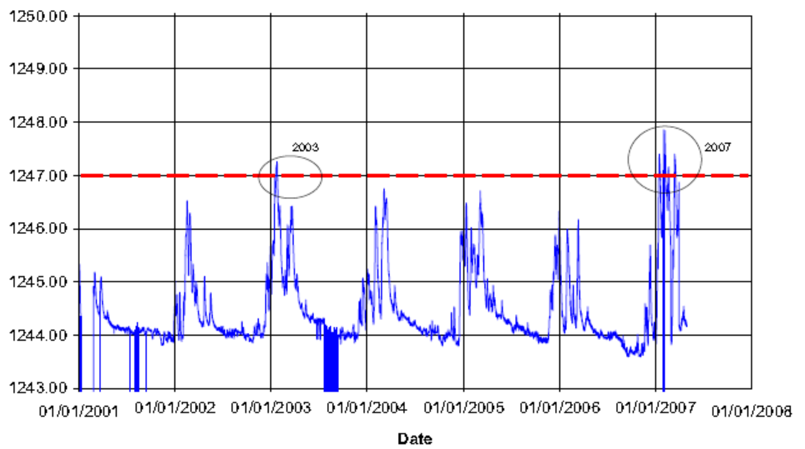

Figure 2 River flow at Bevomange (downstream of city, where pumps discharge) Y axis is height

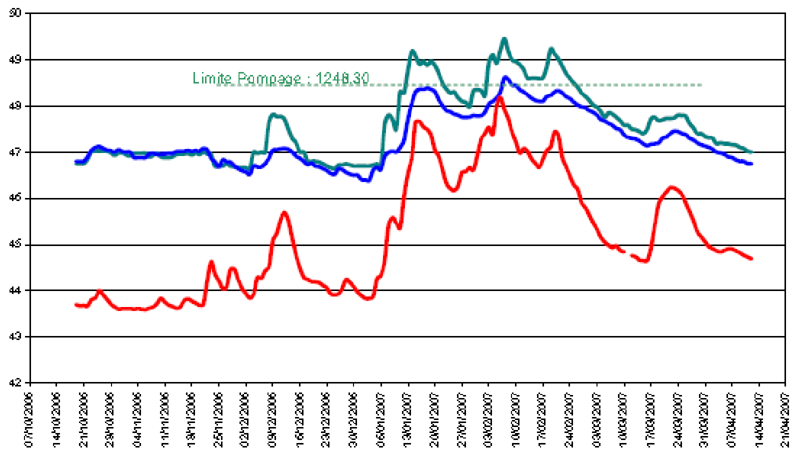

Figure 3 Green line is Mamba, Blue the main canal and red the Ikopa (same station as above). Y axis is height (mAOD – 1200m)

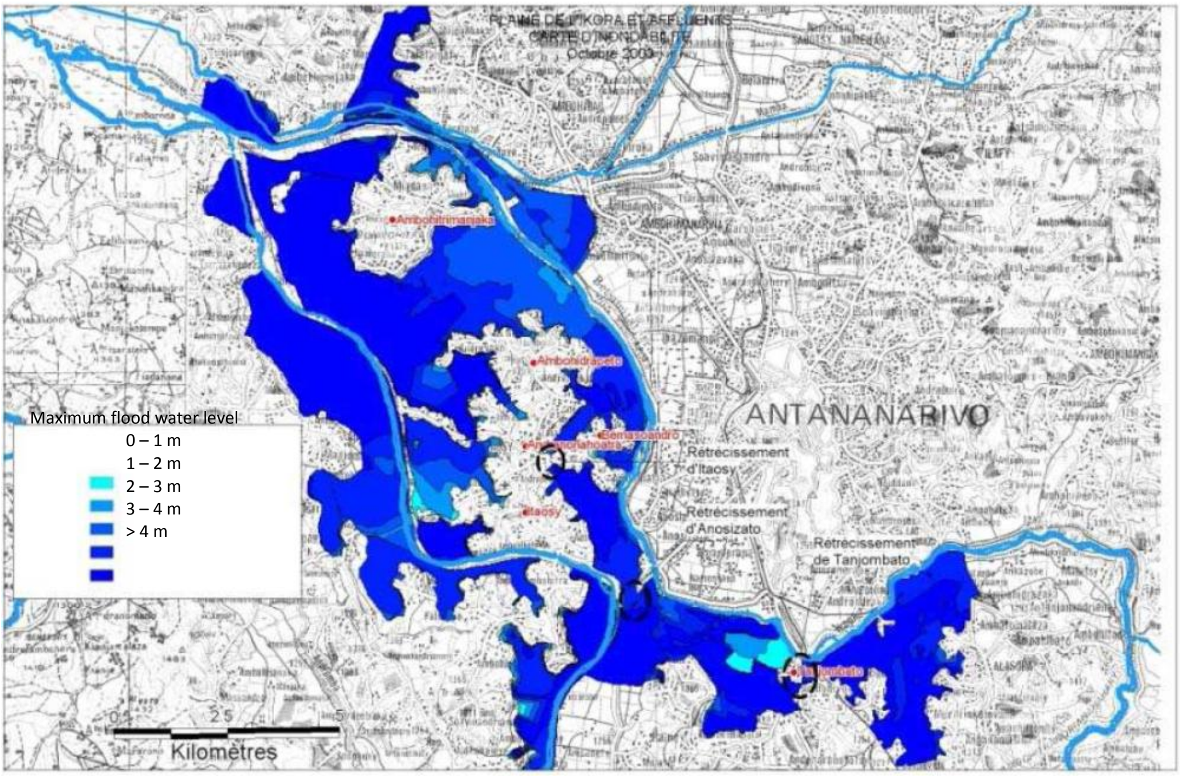

Figure 2 Maximum flood water levels (SOMEAH 2004 in Dresher *et al., 2008)*

Impacts of Climate Change on Antananarivo

Madagascar has severe problems with soil erosion and deforestation, which reduces habitats, soil fertility and productivity, increasing the vulnerability of agriculture and fishing-based livelihoods. Climate change will exacerbate soil erosion and deforestation and ultimately lead to a reduction in food security, income and water quality. Livelihood options will be reduced, leading to livelihood conversion or migrations, which will be compounded by population pressures (increased demand on resources). The changes to climate expected are as follows (refer to the Madagascar Climate Briefing (Heath, 2010) for a more in depth overview):

Climate Changes

The latest assessment of the changes to climate are from a WWF and Conservation International Workshop in 2000, which based its predictions on multiple global climate models (13 for temperature, 6 for precipitation and 4 for cyclones); however, there has been no specific modelling of Antananarivo.

- Temperature: the mean temperature is predicted to increase in Madagascar. The greatest warming is projected in the South (2.6°C by 2055), while less warming is predicted in the coastal areas and the North (1.1°C). In Antananarivo the temperature increase is between 1.3 and 2°C by 2055. Figure 3 displays the maximum and minimum temperature changes predicted for Madagascar
- Rainfall: median rainfall will increase throughout the summer months (November to April). During the winter (May – October) the tropical regions are predicted to be wetter, and have more frequent storms, while the Southern half of the East coast is projected to be drier by 2050. Rainfall intensity is predicted to increase during the rainy season but decrease in the dry season. Antananarivo is expected to be wetter in the rainy season and during summer[1]
- Cyclones: the frequency is predicted to decrease in the early part of the main season, but their intensity and destructive power are expected to increase towards the end of the century

[1] The projections for rainfall are opposite to the observed trend of decreasing rainfall over the last 30-40 years

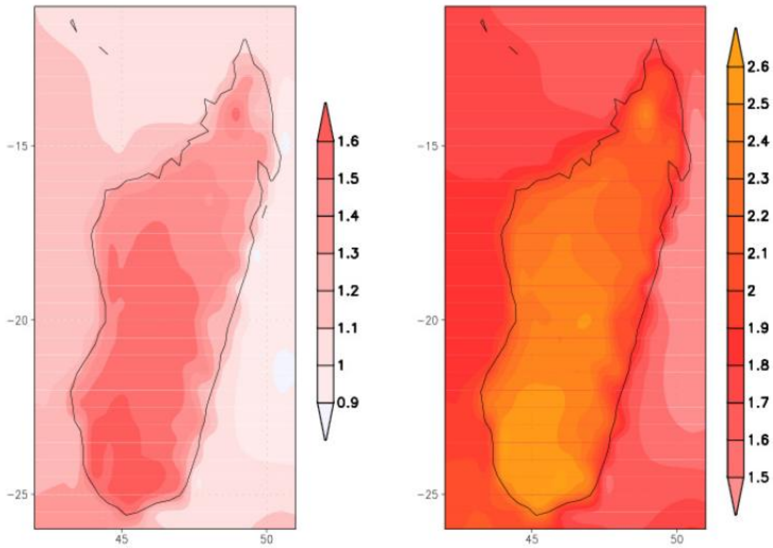

Figure 3 Minimum (left) and maximum (right) projected change in annual temperature by 2055

UNCERTAINTY

"One thing is certain; under climate change uncertainty will increase" (UNWATER, 2009). When making climate change impact assessments, a 'cascade' of uncertainty arises (e.g. uncertainty with modelling, scenarios and data) making it difficult to make reliable predictions. The impacts predicted need to be considered alongside current population pressures and existing vulnerabilities - even without anthropogenic climate change, climate variability undermines food security, negatively affects the environment and significantly affects livelihoods. Therefore the most pragmatic approach is to develop the resilience of water and sanitation systems– managing risks, building their capacity to deal with unpredictable events and prioritising no-regret measures (UNWATER, 2009).

CLIMATE SCENARIO

The changes to temperature and rainfall in Antananarivo have been identified, the magnitude of the changes is less certain but the direction is known. Therefore assessing the impacts can be completed using one scenario, evaluating the impact of increasing rainfall and increasing rainfall intensity. Presently the floodwater sources are runoff from the upper catchment and rising groundwater levels. The increase in rainfall is likely to increase the volume of runoff and raise river levels, while increases in rainfall intensity will increase the speed of the floods. This will lead to an increase in flooding from both the river and the drains. Even if the frequency of flooding does not change, the potential increase in river levels will increase the number of days when the drains can't empty and must be pumped, decreasing the speed water is removed from the city. The increase in rainfall may remediate the shortages for irrigation; however, this may be offset by increased demand associated with higher temperatures. As the extent of the variation in rainfall patterns and volume is uncertain, this report outlines the impacts associated with more significant changes to rainfall and highlights adaptations to increase resilience. Even if this "worse case scenario" is not realised imminently, the changes are likely in the coming decades.

IMPACTS OF CLIMATE CHANGE NOT DIRECTLY RELATED TO WATER AND SANITATION

The following summarises the impacts of climate change on Madagascar not directly related to water and sanitation; refer to the climate change briefing (Heath, 2010) and the second National Communication to the UNFCCC (2010) for a more comprehensive overview. WWF and UNDP are both undertaking analyses of the impacts of climate change but presently no results are available.

Food Insecurity: The increases in temperature and decreases in rainfall predicted in the south will make the climate more arid, reducing crop yields and increasing livestock diseases and death. The increase in temperatures will increase irrigation demands (in particular for sugar cane), decrease yields (by increasing moisture deficits) and may alter the growing season of cereal crops. The increase in rainfall may offset these impacts, but may result in crop failure through flooding or changes to the seasonality of the rains making it more difficult to plan. In addition, more intense cyclones will increase the damage to crops, reducing yields.

Migration: There are a ranges of vulnerabilities associated with climate change, which will threaten livelihoods and are likely to increase migrations, in particular to urban areas. These include crop failures, an increase in desertification in the south, loss of beaches and habitats and sea level rise (7 or 8 cm a year) which may engulf the mangroves making life more difficult for fisherman and shrimp farmers.

Air Pollution: Antananarivo has severe problems with air pollution and an increase in temperature will exacerbate the smog and respiratory diseases.

IMPACT OF CLIMATE CHANGE ON THE INFORMAL AND PERI-URBAN AREAS

The following summarises the impact of climate change on water and sanitation in the informal and peri-urban areas in Antananarivo based on the focus groups and interviews.

CUA

In the informal areas there is likely to be an increase in flooding from the drains. Currently the drains flood throughout the rainy season after 1 hour of heavy rain (APIPA found 60 mm/hour results in inundation). In the communities visited flood water comes to a depth of ½ - 1 m and takes around 2 hours to drain, although some areas have standing water throughout the rainy season. During cyclones, the impacts are more severe as there is more intense rainfall. The increase in rainfall intensity and volume will exacerbate these effects, potentially increasing the severity and frequency of floods. Sewage and garbage is dumped in the drains therefore when they flood they present major health risks (fever, diarrhoea, dysentery respiratory diseases, skin infections and malaria) and disruption to the lives of the communities. The impacts of the floods are as follows:

- Contaminated water enters up to 60% of the houses, causing health problems, unpleasant living conditions and house collapse
- Employment decreases. The main incomes are from laundry and selling goods and these are less viable during floods as it is too wet to dry clothes and people have less money. In addition people can't work as they have to stay at home to care for children and protect their homes
- It is more dangerous to travel, as manholes and culverts hidden and roads are damaged, limiting business, access to school and work
- Food costs increase, charcoal is very hard to find and markets reduce
- Rubbish is washed from other areas
- It is very dirty and odorous, children play in the mud, wooden houses absorb foul water and many of the paths turn to mud, harbouring diseases and making the area unpleasant (this may be exacerbated by temperature rises)

WATER AND SANITATION TECHNOLOGY

The flooding of the drains has severe impacts on water and sanitation technologies. The main issue is collapse of latrine super structure and latrines overflowing, filling houses with sludge and further contaminating the water. When the areas are flooded many latrines are not useable, and the only options are the sanitation blocks or sanitary pails. The latrine blocks installed by CARE and WSUP were designed accounting for flooding risks and are raised above the flood level making them resilient to the floods, but they are too expensive for some households and some have not been effectively maintained and no longer function. The CARE, and WSUP kiosks were designed to account for floods and are resilient as they are built on higher ground; however, the water supplied from JIRAMA is not safe during floods. This is due to the following:

- The catchment for the lake supplying the city is not protected;
- During floods the river has a very high sediment load (the maximum turbidity increases from 80 NTU, to 110 NTU, and remains high 10-15 days after rainstorms) and treatment does not effectively remove suspended sediments which carry bacteria and makes the water yellow
- High non-revenue water (illegal connections and leaks) make ingress of flood water likely, which contaminates supply

In addition, during floods the kiosks have long queues, some taps are submerged and the water pressure is lower so it takes longer to fill containers. The other major problems are people travel through the flood water to reach kiosks, exposing them to disease and water is contaminated when its transported and in the home.

PERI-URBAN AREAS

The impacts on the peri-urban areas need to be considered as three separate zones: the uplands, lowlands and rice paddies. Climate change will have limited impact on the uplands, the only change maybe an increase in the surface runoff and need for attention to drainage paths when locating latrines and pipes. The lowlands and paddies are affected by three sources of flooding, from the river, from the drains and from ground water. Flooding from the main river only effects a small part of the peri-urban areas highlighted on Figure 4, however as the flood bund only provides protection from the current 10 year flood (which is likely to become more regular) the area will flood more frequently. However, this area may be protected as the government plans to establish sacrificial land upstream to remediate the flooding. In addition the tributaries may become more flashy, rising faster and flooding more land. The drains in the lowlands are lower than in the city and flood when there is heavy rain, or problems with the city drains. There is also flooding due to collapse of irrigation dams. The paddies flood when the ground water rise or drains overflow and many of the areas that flood can take up to 3 months to drain.

The impacts on the lowlands are similar to those in the informal areas but there is the additional burden of the damage to crops and livestock. If roads are damaged it is hard to sell crops, food supply is reduced and there is little employment outside farming. In addition, masons can't work as it's too wet, people don't have money for drivers if they get sick and water is expensive. The impacts on water and sanitation are similar to those in the informal areas but as there is more space simple, coping strategies can be applied. One area of concern is the new latrine block built on the riverside of the flood plain in Alosora. There has been no flood since its construction and it has been designed to be resilient (based on WWF recommendation in EIA, 2008) but if floods become more frequent it may not function.

The impacts on the paddies are similar, except ground water has a more significant influence as the paddies are low and ground water is often above the surface, so drain slowly. In the paddies water can rise after 3 to 4 days of rain flooding the area and take up to 3 months to drain, in addition the area can flood if the drains overflow or the bund fails. The impacts of flooding are the same as above but there is also damage to the rice crop, which fails to grow effectively if the water is 1m deep. Also the rice crop can be destroyed if the flooding is combined with high winds (like during a cyclone) as the floodwater weakens the soil and roots and the high winds then flatten the crop.

CLIMATE CHANGE AWARENESS

As well as increasing the resilience of water supply and sanitation systems, working with other organizations to build capacity and share knowledge is key for successful adaptation to climate change. Therefore an understanding of the current climate awareness and actions of the different stakeholders is needed. Table 1 gives an assessment of this information based on stakeholder interviews.

Table 1: Climate change awareness and actions of organizations in Antananarivo

Stakeholder	Awareness	Plans/Actions	No. Interviews
Community	Low	None	9
WSUP	Medium	This report	2
JIRAMA	Medium	Aware need to adapt system	1
Consultants	Medium	N/A	2
Commune/ Council	Low	None	2
Local Organisations	High	Aware of need to do incorporate	2
Government	High	- UNDP platform of exchange and information established - Second communication to UNFCCC just published - Summary of climate change prepared by Meteorological Department - Meteorological Department are mainstreaming climate change with support from presidential level - Climate change department - REDD programme	4
NGOs	2 organisation limited, 1 aware, 4 high and involved with advocacy	- Not incorporated into programmes - Have climate change project officer providing technical support - Focus on disaster preparedness - UNDP comprehensive study of impact of climate change on environment and agriculture	7

Recommendations

Adapting to climate change requires a combination of technological and structural measures, risk sharing and capacity building to increase the robustness of systems. Coping with climate change does not involve many entirely new processes or techniques. It should, however, be made clear that this is not an argument for 'business as usual'. Existing instruments, methods and measures may need to be introduced at a faster pace, and applied in different locations, at different scales, within different socio-economic contexts and in new combinations (CAPNET, 2009). Developing water safety plans should be a priority, to reduce the risks to water supply by establishing a framework for managing the risks to drinking water from catchment to consumer (Bartram 2009).

This section reviews how climate change affects the activities proposed in the *Outline Sanitation Strategic Plan* (SOMEAH 2010b), highlighting what needs to be prioritised and potential modifications. The purpose is to climate proof the strategy; however, it's important to clarify the activities not discussed are relevant for addressing sanitation, but they are not affected by climate change. It then presents a list of the proposed adaptations for areas affected by floods, principally the vulnerable areas identified by SOMEAH (2010a) in the Sanitation Master Plan (Figure 4), but the adaptations are also relevant to other areas affected by floods.

IMPACT OF CLIMATE CHANGE ON SANITATION STRATEGIC PLAN

The vision in the *Outline Sanitation Strategic Plan* is to ensure the Malagasy population as a whole has access to adequate, effective, and sustainable sanitation by 2015, while by 2030 the CUA and FIFTAMA communes will be equipped with excreta, sewerage, storm water and waste disposal accessible to the largest part of the population, including the poor. The strategy presents specific objectives for achieving the 2015 vision (contributing to achieving the overall 2030 vision) which are divided into 6 components (prerequisites, capacity building, hygiene promotion, solid waste, management of excreta and stormwater management) and 39 actions and activities. The following assesses how climate change affects the 6 components of the strategy identifying the activities which will increase the city's resilience to climate change.

Prerequisites and Crosscutting Issues

Climate change does not need to be considered in these activities.

Capacity Building

If the frequency of flooding increases, the need to address the associated risks will be greater, therefore capacity building and educating the communities will be key, in particular educating organisations on the importance of drain maintenance and solid waste disposal. Key activities for achieving this are as follows:

- campaign for sensitizing and informing the population on the rights, roles and responsibilities of the different actors
- capacity building of heads of fokontany on control (land use, sanitation installations, environmental pollutions: unlawful discharge or deposits of sludge, wastes, and sewerage water), in particular addressing the regulation of waste from the upland fokontanys
- Training trainers and disseminating information

Promotion of Hygiene

As with capacity building an increase in the frequency of flooding will increase the exposure of communities to flood water. Hygiene promotion is key to educate the communities of how to best cope with floods to maintain their health. Key activities for achieving this are as follows:

- Definition of appropriate approaches to develop demand for infrastructures and en sure their good use and maintenance.
- Implementation of information, sensitization, and training campaigns on sanitation and hygiene
- Capacity building of local actors for hygiene promotion (Investigate low cost flood proofing)

DOMESTIC WASTE

Poor domestic waste management exacerbates the impacts of flooding as it blocks drains and increases the health risks associated with the floodwater. Therefore dumping of rubbish in drains needs to be addressed; by ensuring communities have adequate disposal options and lobbying. Key activities include the following:

- Improving the service rate of collective dumpsters
- Developing precollection in the 15 fokontanys of the CUA
- Stopping temporary dumping and replacing them with permanent dumping grounds
- Removing unlawful dumping within neighbourhoods

Management of excreta

The main risk from an increase in flooding is the increased exposure to excreta. To reduce the impacts it is crucial that better sanitation technologies are made available, emptying options are improved and funds are made available to try and reduce the amount of sewage onsite. The key activities are as follows:

- Supporting private operators in terms of tank drainage and drainage matters collection
- Studying and starting-up the process of drainage sludge disposal and treatment
- Piloting various means of support to households in funding or acquiring standalone sanitary installations (microcredit, revolving funds etc)

SEWERAGE AND STORM WATER

This is the component of the plan most affected by climate change as the severity of flooding will increase. It is essential the stormwater actions are addressed as the flooding is the main environmental problem in the city and by reducing flooding other problems will be less significant (for example poor excreta and domestic waste management). All of the activities need to undertaken

Flood Adaptations

This section reviews the key adaptations in areas affected by floods for WSUP (and local service providers) JIRAMA and the Communes; Figure 4 displays the areas most affected by floods. The adaptations were determined based on a field visit, a vulnerability assessment and a literature review. Some recommendations will be part of existing maintenance programmes; however, the priority of these actions may need increasing. WSUP Kiosks, laundry blocks and latrines are presently built to high standards and are resilient to floods, the following provides an overview of potential adaptations to design.

The adaptations have been divided into three timescales (based on Venton, 2010). References in brackets provide further information about each recommendation:

- **Short term:** contingency adaptation for extreme events – e.g. Drought management/ flood forecasting, focussed on disaster management experience;
- **Medium term:** tactical adaptations regarding climate variability, linked with disaster risk reduction;
- **Long term:** adaptations necessary to respond to a predicted different climate.

The adaptations categories (based on Charles *et al*., 2010):

- **Capital expenditure**, which includes new investments and projects;
- **Operational expenditure**, which includes adaptations that can be made to existing systems;
- **Monitoring**, which includes programmes that can be implemented immediately to support planning decisions, or implemented in the long term to support continuing decisions;
- **Socioeconomic,** tools such as community education, training and public awareness.

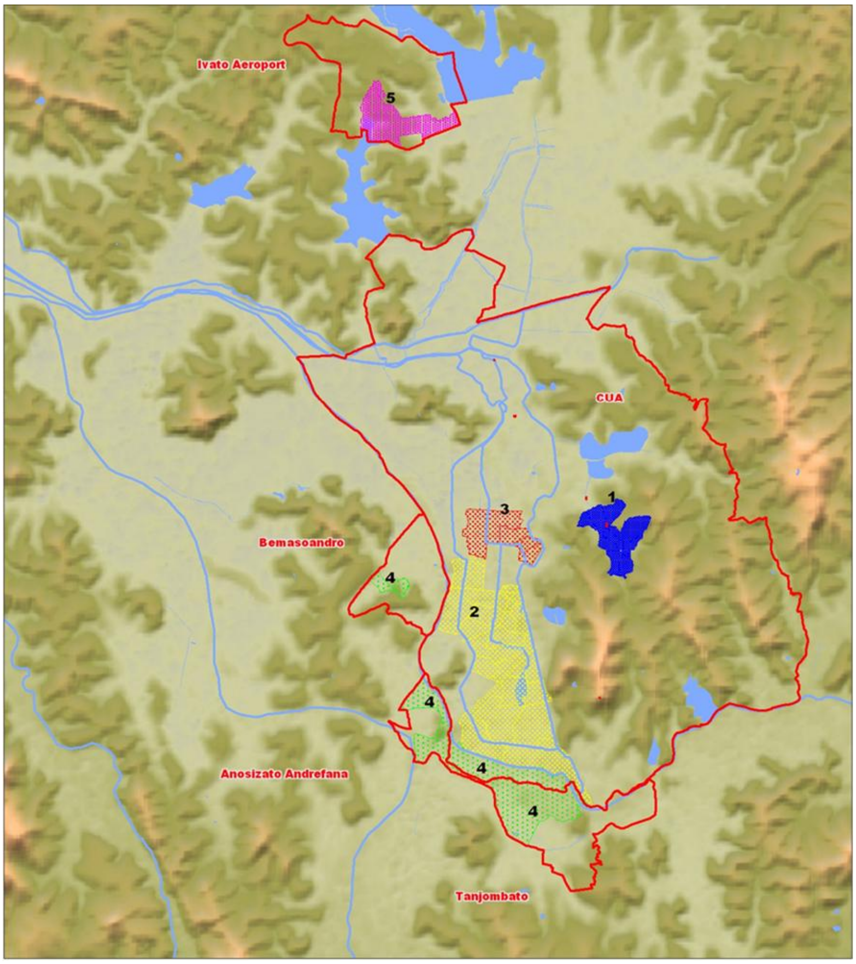

Figure 4 Areas most vulnerable to flooding (refer to SMP for list of full of Fokontanys (SOMEAH, 2010a))

WSUP (CARE OR WATER AID)

The main impacts of climate change in the informal and peri-urban areas in Antananarivo are flooding and the associated health impacts. The local service provider infrastructure is built to a high standard and is resilient to floods, the main issue is the contamination of water supply and overflowing of septic tanks and latrines. The main adaptations to each of these issues are outlined below:

- **Monitor water from kiosks during floods:** to ensure it is safe to drink and adheres to WHO or national drinking water standards. If the water quality deteriorates the water should be chlorinated at distribution and boil water notices should be issued. Once the flooding has ended continue to monitor the water and flush the pipes with a high dose of chlorine
- **Ensure septic tanks are flood proof:** when constructing septic tanks ensure flooding is taken into account. Build them higher than the floodwaters, make sure tanks are attached firmly to ground and it is not possible for water to get underneath, install a flap valve which can be closed during floods, plant trees were possible to stabilise the soil. Build communal infrastructure to high standards but also educate communities on simple methods for making latrines more resilient (raising the platform, having a seal which can block the latrine in floods, building small latrines which are emptied regularly and properly compacting soil around hole
- **Education on risks of flooding:** the health issues associated with floods are exacerbated by the poor management of solid waste and excreta; community education on this will reduce the impacts. Trying to stop communities using the drains as a dumping ground is central to this and education on latrines (as above) will lower the impact. There should also be information on flood adaptations – how to avoid contamination of water in the home and during collection, the need to boil or chlorinate and how stop latrines flooding.

IMMEDIATE/ SHORT TERM (0 – 6 MONTHS)

CAPITAL EXPENDITURE

- Compaction of soil and planting above pipes, sewers, under paved roads etc
- Install non-return valves on septic tanks that can be shut in event of a flood; do not use the septic tank again until waters have receded (refer to WHO, 1996 3.9)
- Repair erosion damage around septic tanks and reseed areas as necessary to provide turf grass cover

OPERATION EXPENDITURE

- Plan after-flooding response to assess and address infrastructure damage
- During floods increase chlorination
- Flush out flooded pipe network after waters have receded to remove sediments (refer to WHO, 1996 2.7)
- Reduce the use of buckets for collecting water by finding supplier of 15L Jerry cans (for children 20 l too heavy and 5l too small)

MONITORING

- Sanitary inspection of standpipes during floods (refer to WHO, 1996 2.1)
- Intensify monitoring of water quality after flooding event and before going back on line, chlorinate if necessary
- Flush out pipes and clean standpipes after floods
- Maintain conditions which mitigate erosion, e.g. compaction of soils and plants in buffer strips
- Regular emptying of septic tank services to minimize faecal sludge build-up
- Septic tanks and pump chambers can fill with silt and debris, and must be pumped out and cleaned after a flood (refer to WHO, 1996 3.9)
- Check the vegetation over the septic tank and soil absorption field after flooding

SOCIAL ECONOMIC

- Disseminate health advisory notices to the public with advice about dealing with the risks of flooding (Refer to Reed, 2006)
- Issue boil water notices where appropriate. Develop communication procedures for when water is safe

- Education about hygiene and cleaning up after flooding (refer to Reed, 2006)
- Hygiene promotion and education on regular maintenance requirements (refer to Appleton and Sijbensema, 2005 & Curtis 2005)
- Raise awareness about the dangers of unstable pit latrines, and under what conditions these occur

MEDIUM TERM (6 MONTHS – 1 YEAR)

CAPITAL EXPENDITURE

- Place kiosks on elevated platform or higher ground to allow access during floods
- Construct standpipes from durable materials to reduce damage during floods
- Land management – minimize erosion with planting schemes, buffer strips and storm water management.
- Use durable materials in construction (refer to ITDF, 2007)
- Where possible, site septic tank away from water supply and design to prevent ingress of silt
- Use durable materials in construction of tanks (refer to EASRWAG, 2008)
- Planting of grasses and shrubs on the absorption area, and around septic tanks, to reduce erosion
- Build bunds (banks, dykes or levees) to divert flow away from system

OPERATION EXPENDITURE

- Adopt a standpipe maintenance programme to reduce potential for ingress (e.g. chambers are sealed)
- Develop response plan after flooding to assess damage to standpipes and to inform future improvement
- Ensure adequate access to septic tanks so that they can be cleaned
- If groundwater rises above the bottom of the septic tanks, the tank will need to be secured to prevent floating during pump out (refer to WHO, 2003)

MONITORING

- Monitor water quality and groundwater levels during flood
- Education to increase awareness of the risks of sewage upwelling if soak ways are waterlogged
- Ensure that septic tanks are emptied regularly
- Increase water quality monitoring after floods have receded
- Monitor water quality and adapt treatment processes to ensure that water quality is not compromised, such as by increasing sedimentation time and improving filtration systems

SOCIAL ECONOMIC

- Raise awareness among the public of contamination issues during floods and extreme rainfall events, this may be done by posting leaflets, door-to-door visits, and radio and television announcements to inform people to boil water
- Ensure septic tanks are full of water during a flood to prevent damage to the infrastructure; however, lids need to be properly fitted and secured to prevent sewage overflow (refer to WHO, 1996 2.1)
- Raise awareness among the community about potential health issues associated with sewage and the damage that erosion can cause to infrastructure, and the potential effect on the water supply system(refer to Appleton and Sijbensema, 2005 & Curtis 2005)
- Raise awareness about potential contamination of drinking-water supply, health issues with sewage and the need for regular emptying of pit latrines

LONG TERM (1 YEAR+)

- Review the risks and benefits of removing the standpipe if it is located in an area at high risk of flooding
- Where possible, site system away from water supply
- Introduce trees and other plants around septic tanks to improve drainage and increase water loss by transpiration
- Promote infiltration of floodwaters (BGR, 2009)

Other Stakeholders

Adaptation to climate change requires an integrated approach from all stakeholders. Alongside WSUP, JIRAMA and the Communes are central for providing water and sanitation in the peri-urban areas. JIRAMA's main priorities should be increasing the resilience of their distribution systems and improving their water treatment. They need to undertake a programme of leak detection, pipe maintenance and reduce illegal connections to minimise contamination of the water supply and improve the hydrostatic pressure; Parker (2010) provides detailed recommendations for reducing NRW. The treatment needs additional treatment stages to deal with the high sediment load during floods, either an additional settling tank which can be used during floods or higher dosage of flocculent. The Communes need to focus on clearing the drains they are responsible for, assisting APIPA in monitoring drains, ensuring the communities don't dump material in the drains and improving waste collection and sanitation options. It is also important they minimise the occupation of areas not designed for habitation on the city plan. The following identifies focused recommendations for JIRAMA and the communes on how they can reduce the impacts of floods in the informal and peri-urban areas. The adaptations for both are split into short, medium and long term adaptations.

JIRAMA

Immediate/ Short term (0 – 6 months)

Capital Expenditure

- Adapt water treatment for flood conditions depending on water source and contamination, introduce additional, more robust barriers and treatment stages (refer to WHO, 2003)
- Protect electrical installations from flooding
- Compaction of soil and planting above pipes, sewers, under paved roads etc

Operation Expenditure

- Plan after-flooding response to assess and address infrastructure damage
- During flood increase chlorination (refer to WHO, 1996 2.27)
- Select appropriate water treatment stages to suit water quality (refer to WHO 2003)
- Dig out buried intakes after flood waters recede
- Flush out flooded pipe network after waters have receded to remove sediments (refer to WHO, 1996 2.27)
- Clean sewers regularly
- Clean drains regularly especially just before wet season

Monitoring

- Intensify monitoring of water quality after flooding event and before going back on line
- Regular inspection of network, including periodic integrity testing and tracer tests

Social Economic

- Disseminate health advisory notices to the public with advice about dealing with the risks of flooding
- Education about hygiene and cleaning up after flooding

Medium Term (6 Months – 1 year)

Capital Expenditure

- Design flood storage areas on rivers to mitigate the impacts of floods, this may include implementing land management activities to increase infiltration of water and reduce severity of floods, e.g. terracing, adequate urban drainage, reforestation, retention basins (refer to BGR, 2009)
- Where possible, aim to site pipes in areas of low risk of flooding; in areas where flooding is likely aim to keep water and sewage pipes separate in case of cross contamination through fractures (refer to Reed, 2006)
- Relocate water pipes away from open sewers and drainage channels
- Land management – minimize erosion with planting schemes, compaction of soils above pipes, buffer strips and storm water management (BGR, 2009)

- Use sustainable urban drainage systems and separate sewers
- Build shallow sewers with flap valves and ensure sewers are gravity flow wherever possible as (lower pumping requirements

Operation Expenditure

- Implement pipe maintenance programme to reduce leakage and the potential for ingress, include cut-off walls in high-risk areas
- Implement rehabilitation programmes to improve hydrostatic pressure (Parker, 2010)
- Implement leak detection and repair procedures (refer to DOH, 2008; EPD, 2007 & WHO, 2001)
- Zoning of water supplies for monitoring and management of distribution system

Monitoring

- Design and implement a monitoring programme for silt build-up in reservoirs and flooding of the pipe network
- Test water quality during major works
- Monitor water quality and adapt treatment processes to ensure that water quality is not compromised, such as by increasing sedimentation time and improving filtration systems.
- Monitor silt levels, blockages, cross connections and so on, in drains and sewers

Social Economic

- Manage communication of early warning of event to the public
- Develop communication procedures for notifying the public when the water is safe
- Raise awareness among the public of contamination issues during floods and extreme rainfall events, this may be done by posting leaflets, door-to-door visits, and radio and television announcements to inform people to boil water
- Raise awareness among water engineers of risks from water quality changes during extreme rainfall events and flooding, how to manage the risks and how treatment can be adapted
- Stop illegal connections to foul sewers

Long Term (1 year+)

- Adopt higher design standards for infrastructure to account for more frequent floods and extreme rainfall, particularly in terms of return periods for significant events (the more expensive option), or have systems that can be quickly and cheaply replaced (refer to WHO, 2003)
- Site water treatment works and other major infrastructure away from flood zones, or build appropriate flood defences
- Smaller more localized treatment systems may help to spread risk of widespread water shortages (refer to Gate, 2001)
- Develop back-up sources, such as linkages to other sources or emergency tank supplies, to mitigate risk of water shortages
- Decentralize and diversify water systems to mitigate the number of people affected in shortages
- Maintain vegetation in buffer strips next to rivers (refer to Gate, 2001
- Install low-cost sewers (easily maintained or replaced when damaged) with spare parts available (refer to EAWAG, 2008)

Commune

Capital Expenditure

- Maintain drains (dredge, clear rubbish)
- Education of pit latrines: installing proper cover to prevent material flowing out in a flood, Investigate overflow mechanisms to filter water to reduce pressure build-up; site latrine away from water supply, areas prone to flooding and drainage channel; Install robust upper foundations, collar and footing to protect from erosion and flooding damage; Small pits to minimize risk of collapse (refer to EAWEG, 2008)
- Advocate making latrine more durable, especially the bottom 30cm, or choosing a cheaper temporary option that can be reinstalled rapidly
- Build bunds (banks, dykes or levees) to divert flow away from latrines

Operation Expenditure

- Enforce regular emptying of latrines (encourage shallow latrines for regular emptying and post-flood rehabilitation to remove silt (refer to Scott and Reed, 2006)
- Regular maintenance essential to limit vulnerability to collapse
- Capacity build fuktontany strengthening the link between levels of management and establish specific tasks and procedures for environmental and sanitation issues
- Need legal standard for Communes on resolving environmental issues

Monitoring

- Monitoring and regulation systems should focus on emptying and faecal sludge management as well as construction of latrines

Social Economic

- Enforce no dumping of garbage or material in drains
- Education/requirements for use of durable materials in construction to protect pit cover, ensure proper compaction of soil around the latrine and presence of adequate base and earth filling to protect pits, pit covers and slabs (refer to ITDG, 2007)

Response to Recommendations

A response to the following questions will be included from WSUP, JIRAMA and the Commune:

1. How will [stakeholder] respond to the climate proofing recommendations?
    a. How will the adaptations be implemented?
    b. How do they impact long term plans?
2. What additional information do you require to apply the adaptations?

Further Information

Climate modelling and climate change adaptation are both areas of continuing research. It is important to be aware of the ongoing work being undertaken which will inform future investments and adaptations. Table 1 illustrates that although climate change is recognised at the policy level, there is little application by organisations and utilities. As policy filters down it will have a greater impact on resource management and it is important to stay aware of changes to policy.

CURRENT RESEARCH AND KEY RESOURCES

- UNDP are undertaking a very comprehensive field surveys with the Meteorological Organisation reviewing of the impacts of climate change on agriculture and water resources in preparation of a Water Master Plan for Madagascar. They have just completed an assessment of the South and expect an assessment of the central region to be complete in 6 months
- UNFCCC have just submitted their second national communication to the UNFCCC, which overviews the national circumstances, indexes green house emissions, overviews the vulnerabilities and adaptations; and options for mitigating emissions and vulnerabilities
- WWF are completing various assessments of the impact of climate change on ecosystem services across Madagascar

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Appendix

Stakeholder Interviews

Table 2 Overview of interviews undertaken in Antananarivo (interviews can be with multiple staff)

Organisation	Number of Interviews
Community	**9**
• Peri-urban	5
• Informal	4
WSUP	**2**
Utility	**1**
• JIRAMA	1
Consultants	**2**
Commune/ Council	**2**
• Water Users Association	1
• Health Municipality	1
Local Organisations	**2**
• APIPA	1
• SAMVA	1
Government	**4**
• ANDEA	1
• Department of Climate Change	1
• Meteorological Department	1
• Department of Town Planning	1
NGO	**7**
• CARE	1
• Catholic Relief Services	1
• Water Aid	2
• UNDP	1
• UN volunteers	1
• WWF	1

LITERATURE REVIEW

In addition to identifying the impacts of climate change on the existing vulnerabilities and problems in the peri-urban areas in Antananarivo the literature was reviewed to assess the impact of climate change on water and sanitation technologies. The following tables overview how the technologies (current and planned) are vulnerable to the key issues and the resulting impacts. The tables are based on observations during the field visit and literature, which assesses the impact of climate change on technology – principally a review completed by the WHO and DFID in 2010 (Charles *et al*., 2010).

Impact of Climate Change on Technology in Peri-Urban and Informal Areas

Utility-managed drinking water systems (direct connections)

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Flooding increases	Increased flooding reduces the availability of safe water resources	Flooding events increase the level of chemical and microbiological contamination in water sources, increasing the risk to public health. Increased suspended sediment load carried by flood waters exceeds the treatment capacity of water treatment facilities	Design flood storage areas on rivers to mitigate the impacts of floods. This may include implementing land management activities to increase infiltration of water and reduce severity of floods, e.g. terracing, adequate urban drainage, reforestation, retention basins. Adopt higher design standards for infrastructure to take higher and more frequent floods into consideration, particularly in terms of return periods for significant events.	Seasonal forecasting. Flood forecasting.	Hydrological monitoring stations. Rain gauging. Earth observation data. Enhanced inspection of infrastructure.	Raise awareness among the public of the risk of contamination during floods and the reduction in drinking-water availability. Dissemination of public health advisory notices with advice about dealing with the issues.
	Flooding of treatment system	Floods may lead to structural damage of the treatment works, or to the failure of pumping stations. Water supplies fail.	Site water treatment works and other major infrastructure away from flood zones, or build appropriate flood defences. Protect electrical installations. Smaller more localized treatment systems may help to spread risk of widespread water shortages.	Plan after-flooding response to assess and address infrastructure damage. Take treatment unit offline and apply corrective action. Increase chlorination. Plan for emergency supplies	Intensify monitoring of water quality after event and before going back on line.	Manage communication of early warning of event to the public. Develop communication procedures for notifying the public when the water is safe. Raise awareness among water engineers of risks
	Surface water quality deterioration during flood	Floodwater carries increased sediment load that may exceed the treatment capacity of the water treatment works. Run-off water from upstream may carry higher concentrations of chemical and microbial contaminants.	Adapt water treatment for flood conditions depending on water source and contamination. Introduce additional, more robust barriers and treatment stages. Relocate abstraction points	Select appropriate water treatment stages to suit water quality. Dig out buried intakes after flood waters recede	Design and implement a monitoring programme of flooding in water sources. Monitor silt build-up in Reservoirs Monitor raw water quality.	Raise awareness among water engineers of risks from water quality changes during flooding and how water treatment can be adapted to manage the risks.
	Entry of contaminated flood water into water supply pipes.	Localized or widespread contamination of the water distribution system.	Where possible, aim to site pipes in area of low risk of flooding. In areas where flooding is likely, aim to keep water and sewage pipes separate in case of cross contamination through fractures. Relocate water pipes away from open sewers and drainage channels.	Implement pipe maintenance programme to reduce leakage and the potential for ingress. Include cut-off walls in high-risk areas. Implement rehabilitation programmes to improve hydrostatic pressure. Flush out flooded pipe network after waters have receded to remove sediments.	Design and implement a monitoring programme for flooding of the pipe network. Review risks and need for refurbishment or replacement.	Raise awareness amongst the public of contamination issues during floods and reduction in drinking water availability. This may be done by posting leaflets, door-to-door visits; radio and TV announcements to inform people to boil water.

	Entry of contaminated water at service reservoir	Localized or widespread contamination of the water distribution system.	Re-line reservoirs. Re-point concrete reservoirs. Replace or repair damaged access points to the service reservoi	Clear drainage channels. Take tanks offline for repairs. Flush tank and distribution before re-commissioning. Repair leaks, drains and valve box. Repair valve if showing signs of wear	Validation by water quality monitoring at times of major works. Regular inspection. Periodic integrity testing. Tracer tests.	Raise awareness among the public of contamination issues during floods and reduction in drinkingwater availability. This may be done by posting leaflets, door-to-door visits, and radio and television announcements to inform people to boil water.
	Contamination of drinking-water in supply affecting large populations.	Major public health ris	Decentralize and diversify water systems to mitigate the number of people affected. Develop back-up sources, such as linkages to other sources or emergency tank supplies, to mitigate risk.	Zoning of water supplies for monitoring and management of distribution system. Implement leak detection and repair procedures	Intensification of water quality monitoring above minimum level specified in WHO guidelines.	Raise awareness among the public of contamination issues during floods and reduction in drinkingwater availability.
Increase in extreme rainfall	Damage to infrastructure.	Potential failure of the drinking-water supply system and loss of service. Public health risk from contaminants entering the water distribution system through damaged pipes	Design or adapt reservoir overflows and spillways to cope with larger flows. Adopt higher design standards for infrastructure to take more frequent extreme weather events into consideration.	Response plan after flooding to assess and address infrastructure damage..	Hydrological monitoring stations. Rain gauging. Earth observation data. Enhanced inspection of infrastructure	Disseminate health advisory notices to the public with advice about dealing with the risks.
	Increased erosion leading to more polluted run-off, with silt and nutrients.	Increase in suspended sediment loads may exceed the treatment capacity of the water treatment facilities. Public health risk from contaminants entering the water distribution system.	Land management – minimize erosion with planting schemes, buffer strips and storm water management.	Maintain vegetation in buffer strips next to rivers.	Monitor water quality and adapt treatment processes to ensure that water quality is not compromised, such as by increasing sedimentation time and improving filtration systems.	Raise awareness among the public of the risk of contamination during and after extreme rainfall events. Raise awareness among water engineers of risks from water quality changes during extreme rainfall events, and how to manage the risk.
Run-off increases	Erosion exposing and damaging pipe work.	Potential failure of the drinking-water supply system and loss of service. Public health risk from contaminants entering the water distribution system through damaged pipes.	Land management – compaction of soils and planting above pipes, under paved roads etc.	Implement leakage reduction plan, as leakage can contribute to landslides.	Hydrological monitoring stations. Rain gauging. Enhanced inspection of infrastructure.	Raise awareness among water engineers of risks from water quality changes from run-off and how to manage the risk..
	Increased erosion leading to more polluted run-off, with silt and nutrients.	Increased suspended sediment loads may exceed the treatment capacity of the water treatment facilities. Public health risk from contaminants entering the water distribution system.	Land management – minimize erosion with planting schemes, buffer strips and storm water management.	Maintain vegetation in buffer strips next to rivers.	Monitor water quality and adapt treatment processes to ensure that water quality is not compromised, such as by increasing sedimentation time and improving filtration systems.	Raise awareness among water engineers of risks from water quality changes from run-off and how to manage the risk. Disseminate health advisory notices to the public with advice about dealing with the risks.

Kiosk/ Standpipe

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Flooding increases	Standpipes inundated with contaminated floodwater.	Standpipes become inaccessible or are damaged by the floodwater. Quality of the water at the standpipe deteriorates and there is potential for more widespread contamination of the distribution system.	Place on elevated platform to allow access during floods. Construct standpipes from durable materials to reduce damage during floods. Review the risks and benefits of removing the standpipe if it is located in an area at high risk of flooding.	Adopt a standpipe maintenance programme to reduce potential for ingress (e.g. chambers are sealed). Develop response plan after flooding to assess damage to standpipes and to inform future improvement. Flush out pipes and clean standpipes after floods.	Sanitary inspection of standpipe. Increase water quality monitoring after floods have receded.	Issue boil water notices where appropriate. Develop communication procedures for when water is safe.
Increase in extreme rainfall	See utility managed piped supply					
Run-off increases	Erosion damaging standpipe.	Destruction of the standpipe and loss of service. Public health risk from contaminants entering the standpipe.	Land management – minimize erosion with planting schemes, buffer strips and storm water management. Use durable materials in construction	Maintain conditions which mitigate erosion, e.g. compaction of soils and plants in buffer strips.	Sanitary survey.	Raise awareness among the community about the damage that erosion can cause to infrastructure, and the potential effect on the water supply system.

Improved pit latrines

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Flooding increases; Increase in extreme rainfall events; run-off increases	Pit overflowing or inundated; very mobile contamination	Faeces leaving pit and causing pollution downstream. Silt and solids entering pit and filling it	Design pit to allow regular emptying and post-flood rehabilitation to remove silt. Proper pit covers to prevent material flowing out in a flood. Investigate overflow mechanisms to filter water to reduce pressure build-up. Where possible, site latrine away from water supply, and away from areas prone to flooding. Build pit latrine superstructure at the same level as the houses, as these usually are above normal flood level. In urban areas, consider small pits which need regular (monthly or less) emptying to minimize the amount of faecal matter exposed to flooding. Consider if dry or composting latrines or sewerage is appropriate	Regular pumping or emptying of pit latrine (particularly in urban setting)	Monitoring and regulation systems should focus on emptying and faecal sludge management as well as construction of latrines – to ensure that systems are in place	Raise awareness about potential contamination of drinking-water supply and need for regular emptying
	Increased intentional emptying of pits during floods	Widespread contamination with faeces		Regular pumping or emptying of pit latrine (particularly in urban setting)	Monitoring and enforcement systems should focus on emptying and faecal sludge management, as well as construction of latrines – to ensure that systems are in place	Raise awareness about potential health issues associated with sewage. Raise awareness about potential contamination of drinking-water supply
	Inundation or erosion	Collapse of latrine	Site latrine away from drainage channel. Use durable materials in construction to protect pit covers. Proper compaction of soil around the latrine and presence of adequate base and earth	Regular maintenance essential to limit vulnerability to		Hygiene promotion. Education on regular maintenance requirements

			filling to protect pits, pit covers and slabs. Install robust upper foundations, collar and footing to protect from erosion and flooding damage. Small pits in urban areas to minimize risk of collapse. Build bunds (banks, dykes or levees) to divert flow away from latrine. Planting of shrubs around the pit to reduce erosion damage. Adopt more conservative design standards for infrastructure to take higher and more frequent events into consideration (more expensive), or have systems that can be quickly and cheaply replaced	collapse		
	Damage to the superstructure		Make more durable, especially the bottom 30cm, or choose a cheaper temporary option that can be reinstalled rapidly			
	Latrine not accessible		Find a new site, not subject to such frequent flooding, or construct temporary latrines in refuges			
	Erosion	Collapse of latrine	Site latrine away from drainage channel. Use durable materials in construction to protect pit covers. Proper compaction of soil around the latrine and presence of adequate base and earth filling to protect pits, pit covers and slabs. Install robust upper foundations, collar and footing to protect from erosion and flooding	Regular maintenance essential to limit vulnerability to collapse		Hygiene promotion. Education on regular maintenance requirements
Groundwater tables rising	Inundation of the pit from below	Contamination of groundwater and soil, potentially reaching drinking-water resource	Provide protected water supply. Consider options: shallower pits and more frequent emptying; dry composting latrines; sewerage.	Regular pumping or emptying of pit latrine (particularly in urban setting) – link to smaller pit sizing	Monitor drinking-water quality	Education to increase marketing and user education of alternatives
	Inundation of pit	Pit collapse.	Build round pits instead of square to increase stability. Use durable materials in construction to protect pit covers. Proper compaction of soil around the latrine and presence of adequate base and earth filling to protect pits, pit covers and slabs. Install robust upper foundations, collar and footing to prevent collapse. Small pits in urban areas to minimize risk of collapse. Introduce trees and other plants to improve drainage and increase water loss by transpiration			Raise awareness about the dangers of unstable pit latrines, and under what conditions these might occur

SEPTIC TANKS

Issue	**Vulnerability**	**Impacts**	**Adaptations**			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Flooding increases; Increase in extreme rainfall events; run-off	Back flow of sewage into the house		Install non-return valve that can be shut in event of a flood; do not use the septic tank again until waters have receded	Regular emptying services to minimize faecal sludge build-up		Raise awareness about potential health issues associated with sewage
	Inundation of the system, resulting in contamination of surrounding area		Where possible, site tank away from water supply			Raise awareness about potential health issues associated with sewage

increases	with sewage					
	Flooding of septic tank resulting in accumulation of silt		Design to prevent ingress of silt	Septic tanks and pump chambers can fill with silt and debris, and must be pumped out and cleaned after a flood. Ensure adequate access to tanks so that they can be cleaned		
	Flotation	Structural damage to tank, for example from movement	Use durable materials in construction of tanks			It is important that tanks are full of water during a flood to prevent damage to the infrastructure. However, lids need to be properly fitted and secured to prevent sewage overflow. Education and increased awareness of issues surrounding damage and when to replace
	Flooding of the absorption field with sewage sludge		Install non-return valve that can prevent flow to the field in event of a flood			
	Inundation of the soakaway		Delay using septic tank until flood waters and groundwaters have receded			Raise awareness of signs of failure of an absorption field, and how to fix it or construct a new one
	Erosion of soil around the tank and absorption field	Damage to infrastructure. Reduced efficacy of the absorption field	Planting of grasses and shrubs on the absorption area, and around the tank, to reduce erosion. Repair erosion damage and sod or reseed areas as necessary to provide turf grass cover. Build bunds (banks, dykes or levees) to divert flow away from system	Check the vegetation over the septic tank and soil absorption field after flooding		
Groundwater tables rising	Flotation of septic tank	Damage to infrastructure		If groundwater rises above the bottom of the tank, the tank will need to be secured to prevent floating during pump out		Education and increased awareness of issues surrounding damage and when to replace
	Inundation of soakaway	Increased potential for contamination of groundwater. Treatment of sewage by soil in soakaways may be reduced Septic tank fills and backs up	Use shallower infiltration trenches or introduce artificial wetlands or reedbed systems to improve effluent treatment. Where possible, site system away from water supply. Design septic tank systems in conjunction with drainage to lower the groundwater table. Introduce trees and other plants to improve drainage and increase water loss by transpiration		Monitor water quality and groundwater levels	Education to increase awareness of the risks of sewage upwelling if soakaways are waterlogged. Ensure that septic tanks are emptied regularly

SEWERS

Issue	Vulnerability	Impacts	Adaptations			
			Capital expenditure	Operational expenditure	Monitoring	Socioeconomic tools
Flooding increases; Increase in extreme rainfall events; run-off increases	Erosion	Same as improved Pit Latrines				
	Infiltration of flood water into sewer, leading to plug flow of pollutants and resuspension	Overloading of treatment works. Pollution of water resources downstream. Ingress of silt	Use sustainable urban drainage systems and separate sewers. Encourage decentralized systems	Clean sewers regularly. Clean drains regularly especially just before wet season	Monitor silt levels, blockages, crossconnections and so on, in drains and sewers	Stop illegal connections to foul sewers
	Rising receiving water levels.	Overloading of sewers, leading to backing-up.	Shallow sewers. Flap valves.			
	High flows cause sewers to flood into environment and houses	Decrease diameter of pipes to attenuate and store water. Separate sewage and stormwater systems. Consider use of small bore or other low-cost sewerage options at local level to reduce costs of separate systems. Design decentralized systems to minimize impact of local flooding				Education about hygiene and cleaning up after flooding
	Treatment and pumping systems cannot work if electricity is affected		Ensure that sewers are gravity flow wherever possible. Low-cost and shallow sewers have much lower pumping requirements	Local decentralized treatment will reduce pumping costs and enable local responsive management when system is vulnerable to damage		
	Erosion exposing and damaging pipe work, especially simplified sewerage		Site pipe away from drainage channel. Compaction of soil and planting above sewers, under paved roads etc. Adopt more conservative design standards for infrastructure to take more severe and more frequent extreme weather events into consideration (the more expensive option), or have systems that can be quickly and cheaply replaced	Low-cost sewers can be more easily maintained or replaced when damaged, but are more vulnerable to erosion. Have spare parts available		
Groundwater tables rising	Sewer surrounded by water	Overloading. Damage to sewer (scouring or washout of bedding, and flotation leading to cracking of the sewer pipes)	Do not locate sewers in soils which are regularly waterlogged. Low-cost and shallow sewers may be less susceptible and above groundwater levels			

Appendix H: Climate Change Summary Report

HOW TO CLIMATE PROOF WATER & SANITATION SERVICES FOR THE URBAN POOR

Executive Summary

Climate change has many uncertainties, but in general we can expect increases in temperatures, the intensity of precipitation, storms, droughts and extreme events; changes in average precipitation are less certain but will become more erratic, shifting in season. For water and sanitation providers climate change will tend to exacerbate or relieve existing vulnerabilities rather than creating new issues. The impact on individual projects depends upon their particular vulnerabilities. To adapt, water and sanitation providers need to increase the robustness of their systems by assessing the impacts across multiple scenarios. Populations will be impacted by climate change in other ways too and this may affect their ability to access water and sanitation services. The impacts must be considered within the context of population growth, urbanisation and environmental degradation. For providers, the most pragmatic approach is to ensure resilience to environmental change and preparedness for disasters.

Tom Heath, Alison Parker & Keith Weatherhead, 2010

WSUP Water & Sanitation for the Urban Poor

Cranfield UNIVERSITY

INTRODUCTION

This report is based upon a 10 month project assessing the vulnerability of WSUP (Water and Sanitation for the Urban Poor) projects to climate change, converting climate change predictions into recommended adaptations. The findings are based on a literature review and field work in Kenya, Madagascar and Zambia, undertaking focus groups, stakeholder interviews and observations. This report synthesises the science of climate change, the impacts of climate change on drinking water and sanitation, how to climate proof water and sanitation services and how to adapt:

Climate Change Science

There is an abundance of reports and forums on climate change and water. However, most present similar information and recommendations based on common sources. The majority focus on the regional and national level with few addressing the project level or specifics for water and sanitation services. Two of the most pragmatic reports are an assessment of resilience (Vision 2030) undertaken by DFID and the WHO[1], and ongoing work by the IRC[2] on adaptation of water sanitation and hygiene services delivery. The main aspects relevant to water and climate change are:

- The scientific community widely accept that climate change is a reality[3]. The Inter governmental Panel on Climate Change (IPCC) has concluded that human activities are altering our climate system and will continue to do so[4]. Figure 2 summarises the process and threats of climate change
- Air temperature and potential evaporation are projected to increase globally (there is less certainty for actual evaporation); precipitation is projected to increase, but the changes vary geographically and temporally (increasing at high latitudes; but uncertain at low latitudes [4]); global sea level is expected to rise by 0.18 m to 0.59 m by the end of the century[5]
- Climate changes may occur as one of three climate change trajectories (Figure 1):
    - A gradual change in "mean" climate;
    - Changes in the degree of climate variability around some mean value (e.g. increasing frequency and degree of extreme weather events);
    - "Modal" change in climate (shift from relative stability to rapid[6] change e.g. melting of a glacier).

  The 2 latter projections are very difficult to model[5]
- Warming of the atmosphere and ocean will change major weather systems, which will alter the temporal and spatial patterns of rainfall. There will be consequences for runoff, surface water and groundwater[4]
- Water is the primary medium through which climate change will influence the Earth's ecosystems, affecting food availability, utilisation and the livelihoods and well-being of societies[7]
- Climate change is expected to exacerbate current stresses on water resources from population growth, urbanisation and economic and land-use change[8]. For example water stress will increase due to increases in physical scarcity and economic and social scarcity driven by changes in demand for water[6]
- Problems with water resource management impacts hamper economic performance and increases poverty[9]
- Globally, the negative impacts of future climate change on freshwater systems are expected to outweigh the benefits[4]

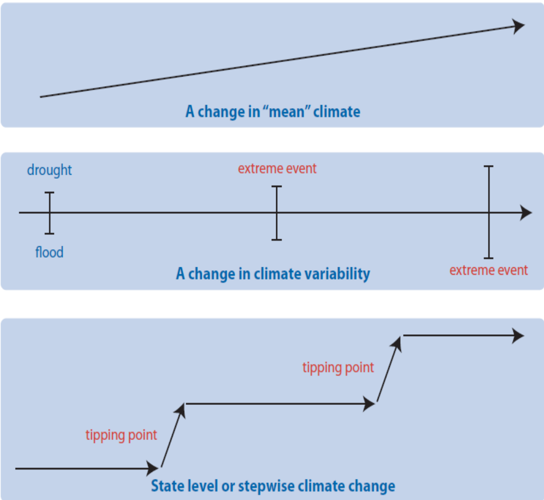

Figure 1: Climate Change Trajectories[5]

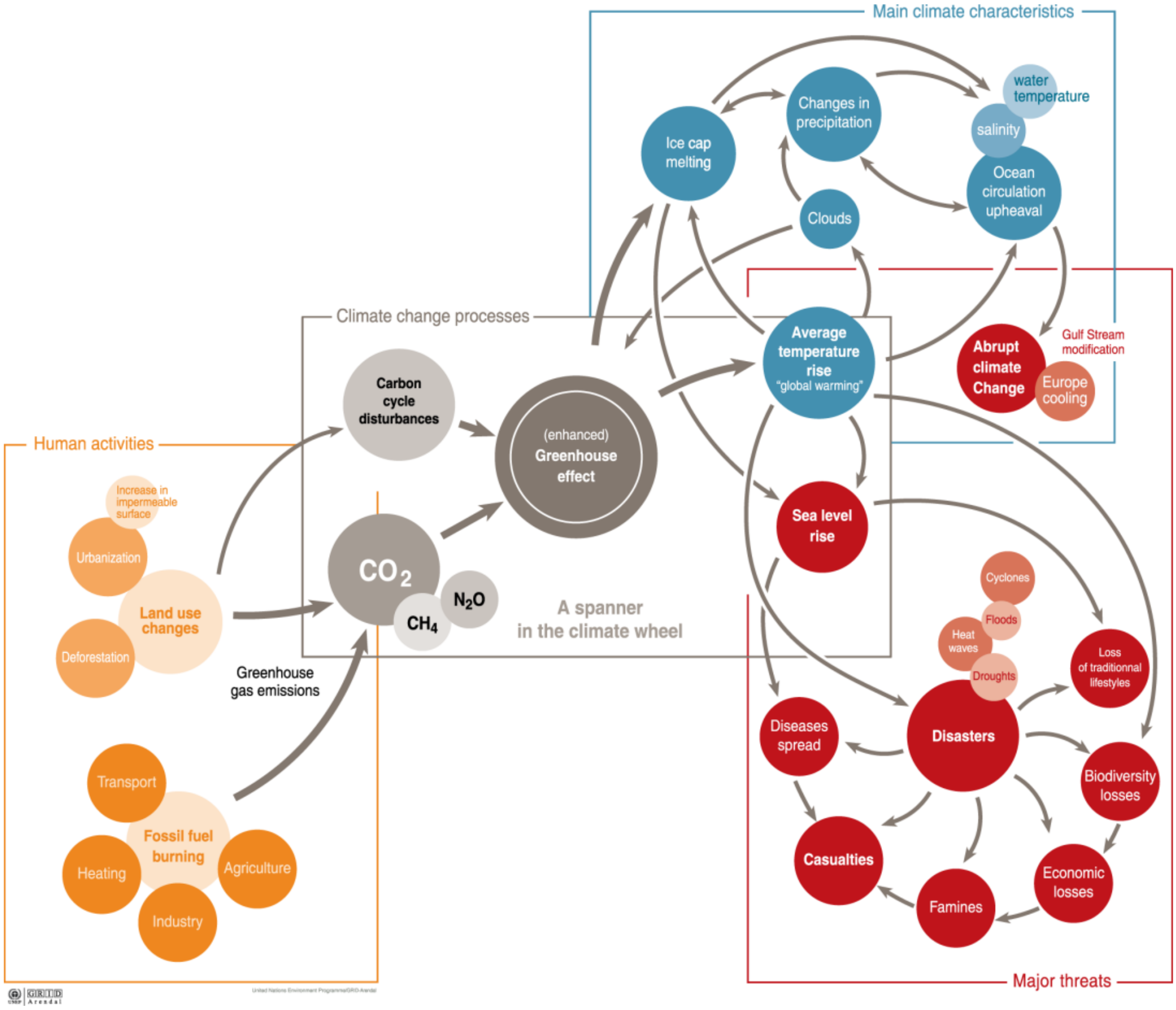

Figure 2: Climate change: processes, characteristics and threats[10]

Uncertainty and Context

"One thing is certain; under climate change uncertainty will increase[8]"

When making climate change impact assessments, a 'cascade' of uncertainty arises, making it difficult to make reliable predictions[8]. For example individual results vary in both magnitude and scale depending on the scenario and global climate model used. However, the main uncertainties are not from inadequate scientific understanding, but from social and economic factors. Therefore climate change must be considered within the context of current population growth, unplanned urbanisation, future strife and/or wars and existing environmental vulnerabilities. Even without anthropogenic climate change, climate variability undermines food security, negatively affects the environment and significantly impacts livelihoods.

Previous Studies on the Impact on Drinking water Supply and Sanitation

Water is at the root of a complex vulnerability dynamic, which is intensified by climate change impacting the hydrological cycle affecting water supplies, river flows and groundwater[9]. For drinking water and sanitation, the affects are realised through floods, water shortages (droughts), increases in rainfall intensity, changes to the seasons, decreased water quality and less predictable weather, which makes it difficult to manage water resources and affects the function and operation of existing water infrastructure. There will also be opportunities associated with climate change, for example, increases in rainfall in arid regions or rainfall reductions in flood prone areas. But, positive impacts are uncertain, and in general drier regions will become drier and wetter regions wetter. Vision 2030 (2010) analysed the vulnerability and adaptive capacity of improved water and sanitation technologies (as defined by the WHO) and management approaches to three rainfall scenarios (increasing/decreasing rainfall and increasing rainfall intensity)[1]. The work was based on background studies of resilience, climate forecasts and interviews. The impact on water resources and water and sanitation technologies is defined in Table 1.

Table 1: Summary of the impacts on water resources and water supply and sanitation facilities of each climate scenario[1]

Rainfall Scenario	Impacts on water resources	Impact on water supply and sanitation facilities
Increased amount of rainfall	- Increased frequency of flooding - Deterioration of water quality - Increased groundwater recharge and rising groundwater levels	- Damage to both water supply and sanitation facilities - Flooding of sanitation systems resulting in contaminated flood waters which further contaminate the water supply and distribution system - Ingress of groundwater into pipe networks, septic tanks and pit latrines - Increased transport of contamination in soils and aquifers
Decreased amount of rainfall	- Falling groundwater levels - Low surface water volumes - Deterioration of water quality - Changes compounded by increased temperatures and evapotranspiration	- Salinity of groundwater increases - Sewage in rivers becomes less diluted decreasing water quality - Increased algal growth - Insufficient water makes flush-sanitation systems redundant
Increased intensity of rainfall	- Changes in groundwater recharge - More run-off resulting in more erosion and greater transport of contaminants to surface water - Flash flooding - Deterioration of water quality	- Increased turbidity resulting in requirement for better sedimentation and filtration in surface water treatment plants - Damage to both water supply and sanitation infrastructure from flash flooding

Vision 2030 also assessed the resilience of technologies to each rainfall scenarios[1] (Figure 4). The resilience was categorised as high (resilient to most possible climate changes), medium (resilient to a significant number of possible climate changes) and low (resilient to a restricted number of climate changes). This information enables organisations to overview the resilience of their infrastructure to the different scenarios. By understanding the current resilience, water and sanitation providers can identify the technologies which are most vulnerable and what the affects will be using the Vision 2040 technical reports[11].

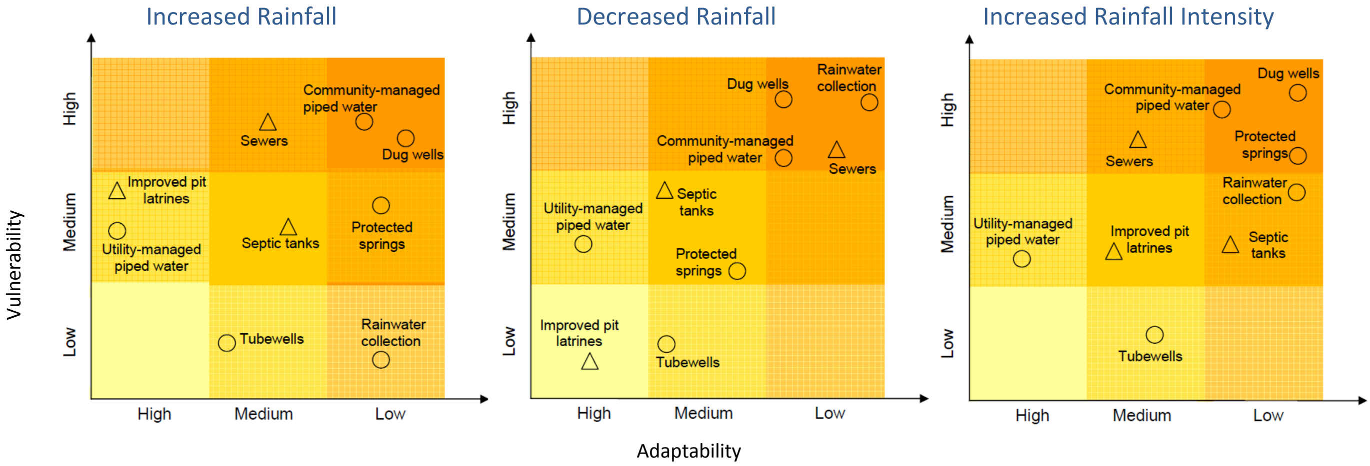

Figure 4: Resilience of water and sanitation technolies[1]

The Impact of Climate Change on low-income urban communities

The impact of climate change was assessed in three cities where WSUP works (Antananarivo[12], Lusaka[13], and Naivasha[14]) through a series of field visits involving observations, key informant and community interviews. Using the climate change predictions for the country, rainfall scenarios were identified for each city and the impact on the hydrological cycle determined. This was one of the most uncertain aspects of the vulnerability assessment. For example, in Naivasha despite there only being one rainfall scenario (decreasing rainfall) two scenarios linked to the lake levels were assessed to account for uncertainties associated with runoff and infiltration,. Once the impacts were estimated, it was possible to identify the vulnerabilities using Vision 2030.

Table 2: Summary of the climate scenarios assessed for the three cities and the impacts on the low income areas

	Lusaka - Zambia	Naivasha - Kenya	Antananarivo - Madagascar
Climate Scenarios	**2 Scenarios:** **- Increased rainfall and rainfall intensity:** Increase in river flow, groundwater levels and localised flooding **- Decreased rainfall and rainfall intensity:** Decrease in water table and river levels. Increase in groundwater abstractions, increased irrigation abstraction from river, decrease in river's water quality	**1 Scenario:** **- Decreased rainfall and increased rainfall intensity, but 2 lake scenarios*:** **- Increased lake levels:** Increase in rainfall intensity in the upper catchment results in increased runoff and river flow, offsetting the increase in evaporation at the lake, maintaining the lake level **- Decreased lake levels:** Significant increases in evaporation from the lake (and irrigation demand); rainfall decreases and is more sporadic offsetting the increase in intensity and runoff	**1 Scenario:** **- Increased rainfall and rainfall intensity:** Increase in runoff and river levels in the upper catchment, river is more flashy and water table rises. Reduction in number of days drains can gravity drain to river. Result is an increase in the frequency of riverine flooding and inundation from the drains
Impact on Peri-Urban and Informal Areas	**Increasing Precipitation:** Kanyama is most at risk to an increase in precipitation, resulting in an increase in flooding (currently Kanyama's floods last for 3 months). Flooding causes kiosks and buildings to collapse, contaminates water supplies (particularly the shallow wells used in the unserved areas) and affects livelihoods, education and health. Flooded latrines and contaminated water will increase cholera and diarrhoea. In Chazanga there will be flood damage to boreholes, kiosks, septic tanks and pit latrines and poor drainage at kiosks. **Decreasing Precipitation:** Chazanga is most at risk to a decrease in precipitation which will lead to a lower water table. This will result in water scarcity, damage to infrastructure and drying up of shallow wells, all of which will increase the demand for new kiosks. In addition, decreased rainfall will affect hydroelectricity generation and cause power shortages. There will be a positive impact on Kanyama, as it will reduce the risk of the drains flooding and lower the water table. However there will be more migration exacerbating land pressures	**Decreasing lake and ground waters** will have a significant impact as there will be higher domestic demand whilst surface water availability decreases. During droughts there are longer queues, water from vendors is more expensive and it takes longer to collect. As a result, water use decreases, hygiene deteriorates and disease increases. The lake area reduces and there is increased conflict between pastoralists and farmers; tourism and fishing suffers, there is reduced employment (in particular from the flower and vegetable farms as they are less profitable to run) and the lake's quality deteriorates. The main problems cited by the community during previous droughts were a decrease in income and the increased cost of food and water. There was little impact on the borehole supply (as it is a confined aquifer) and latrines **Increasing lake and groundwater levels** is largely positive for Naivasha as there is more water for domestic and irrigation use. The main problem is an increase in the number and intensity of flash floods. This increases the amount of garbage and silt washed into the lake, causes latrines to collapse and overflow, exposes pipes, damages houses and crops and inundates roads which disrupt local business. However, flash floods are only an inconvenience to the community as they are able to harvest the increase in rainwater, but there is an observable increase in disease	**Increase in flooding (river and drains):** In the informal areas there will be an increase in the frequency and severity of flooding from the drains. This presents major health risks and disrupts the lives of communities. Water will get into houses, employment will decrease, it will be more difficult to travel, food costs will increase and the environment becomes dirty, odorous and very unpleasant. The infrastructure installed by CARE, WSUP and WaterAid is resilient to flooding, but the water supplied by JIRAMA is contaminated during floods as the catchment isn't protected, increased run-off leads to soil erosion giving the water a high sediment load and there is high non revenue water. In addition, household latrines overflow, their superstructures collapse, flying toilets increase (as latrines are flooded), there are long queues at kiosks, taps are submerged and the water pressure is lower. Peri-Urban areas: In the uplands they will experience an increase in surface runoff, while the lowlands and paddies will flood from drains. Areas near the river will also flood. The impacts are similar to the informal areas but there will also be damage to crops and livestock, whilst opportunities for alternative employment will decrease. However, in the per-urban areas there is typically more space to implement local coping mechanisms. When the paddies flood the water will take longer to drain due to higher groundwater.

* In Naivasha the scenarios are based around lake levels due to uncertainties with rainfall and evaporation and the affect on infiltration and runoff

In the three cities assessed, eleven communities were visited of which eight were vulnerable to flooding and four to water shortages. The impacts of the rainfall change upon areas at risk of flooding and drought were very similar across all three cities. Figure 3 summarises these, indicating that climate change won't always be negative and for certain scenarios, it will have a positive impact on communities (e.g. increased rainwater harvesting associated with increased rainfall). However, in most cases the negative aspects will be more significant.

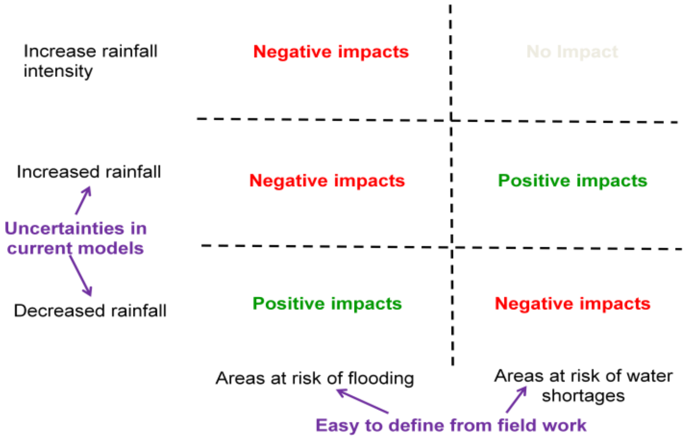

Figure 3: Impacts of climate change on flood and drought prone areas

The impacts on drought and flood prone areas can be divided into regional and local scales and are detailed in Table 3. Regional impacts are more significant, as they affect more people, require more finance and need intervention from governments and other institutions. For example, during a regional drought food shortages impact everyone, reducing available incomes. The main differences between the cities arose from the impacts of climate change on other sectors, which stressed existing systems. For example, droughts affect food prices, hydroelectric production and increase the demand for water, which is combined with reduced employment and an increase in the cost of consumables, especially charcoal and staple food crops (e.g. maize or rice). Climate change also affects the management and governance of water providers, as resources will be strained - increasing conflict over allocation and access.

Table 3: Impacts on the low-income areas

	Flooding	Droughts
Local	**Localised: If drainage capacity is inadequate:** - Latrines overflow - Roads damaged/impassable increasing the cost of charcoal and food - Pipes exposed - Siltation of water resources - Latrines/buildings collapse - Water in houses - Disease increases especially malaria, dysentery and diarrhoea[15] - Solid waste dispersed - Employment deceases - Taps submerged - Income generating activity decreased - Contamination of boreholes	- Water shortages - Water cost increases - Livestock suffer - Crops destroyed - Less water for health and hygiene - Long queues at kiosks/borehole - Increased poverty - Education suffers (less money for school fees) - Malnutrition - Health issues - Water pressure drops
Regional	**River: If riverine flood defences are breached:** - All the above factors plus: - Crops damaged - Road network damaged - Drowning - Infrastructure damage - Increased treatment costs	- Hydroelectric shortages - Water bodies dry up - Food insecurity – food costs increase - Increased conflict

Is Climate Change Relevant

"If a project is sensitive to climate variability, it is likely to be sensitive to climate change[16]"

Every project should assess whether climate variability or change could compromise the integrity, effectiveness, or longevity of the project within the planning horizon for the project. USAID[16] outline a process for assessing the vulnerability of a project, based on the project cycle, which can be utilised for standalone projects or incorporated into existing projects (Figure 5 outlines the steps). If a project is supported by USAID their Global Climate Change team[17] may assist in the assessment. During this study the USAID [ActionAid[18] and Cristal[19]] methodologies were adapted to focus upon water and sanitation. First a rapid screening process should be undertaken by project staff, to determine if the project is vulnerable to climate change. The screening process is outlined below. If this indicates the project is sensitive to climate then a more in depth analysis should be undertaken. This needs to be tendered to an organisation with climatic, hydrological and social data gathering experience, with knowledge of the area; terms of reference have been prepared[20]. Alternatively, if the project team have a clear understanding of the vulnerabilities, appropriate adaptation can be identified internally (further guidance is provided in TOR Guide[21]).

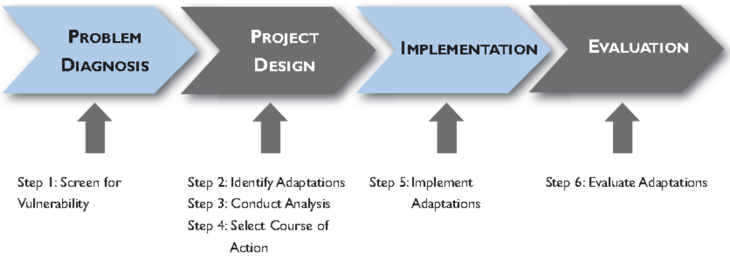

Figure 5 Climate change vulnerability and adaption process

Rapid Screening Process:

1. **Collect Resources (details in TOR guide[21])**
   - Read the countries National Action Plan for Adaptation[22]
   - Read UNEP climate change profile[23]
   - Read the countries national communications to the UNFCCC[24]
   - Download Earthscan and FAO AQUASTAT data sheets[25]
   - Determine current understanding of climate change (contact or search for documents prepared by Meteorological or Climate Change departments/organisations)

2. **Assess Significance of Climate Change**
   1. Discern the projected change to climate (precipitation, temperature and extreme events)
   2. Develop a set of plausible (although not necessarily equally likely) scenarios based on the three rainfall scenarios that describe different futures (recognising the future is not necessarily like the past[4]), ideally encompassing the range of possible changes
   3. Estimate the impact on the hydrological cycle of each scenario, in particular changes to runoff/infiltration
   4. Use vulnerability and risk assessments to gauge the potential impact of climate change on:
      - The country as a whole and the sectors not directly related to water and sanitation and how they will impact water and sanitation systems (including the impact on vulnerable sectors, agriculture and livelihoods)
      - The water resources and water supply (review what the main utilities and regulators are planning for future water supply; in particular changes in demand, quality and variability)
      - The project, assessing the impact on supply, demand, livelihoods and the community
      - Water and sanitation technologies (reviewing the resilience of each technology)

3. **Plan Adaptations**
   A. If impacts are understood and significant – plan adaptations and mitigation measures; guidance is available in TOR notes[21] and USAID guide[17], otherwise tender impact assessment.
   B. If impacts are unknown or unclear– tender impact assessment
   C. If Impacts are understood but not significant – keep aware of updates to forecasting and impact assessments

Climate change Adaptation

"Responses to climate change must focus on water"[7]

Adapting to climate change requires a combination of technological and managerial measures, and capacity building to increase the robustness of systems. Coping with climate change does not involve many entirely new processes or techniques. It should, however, be made clear that this is not an argument for 'business as usual' and climate change adaptations should not simply be 'bolted on' to existing plans. Instead they need to be properly assessed, as future long term changes can introduce new unexpected risks to projects[17]. In particular, changes to extremes (changes to climate trajectories – Figure 2) and risks arising from an increase in rainfall intensity should be considered. These are conditions which may not be a current risk, but predicted increases in intensity will increase runoff, nutrient pathways and localised flooding (often of highly contaminated water).

Water providers should not consider climate change in isolation, but rank and prioritise it against other sources of risks and uncertainty, focusing on increasing the environmental resilience and disaster preparedness of projects[26]. In general, for projects where there is a clear understanding of environmental issues and how to mitigate them (for example, flooding in Antananarivo), climate proofing will be less urgent as strategies addressing these will lower the climate change risk. However, climate proofing will still be applicable and necessary to identify potential new risks and priorities for action. In particular, when rainfall trends reverse or there are dramatic changes predicted (e.g. rainfall that is currently increasing is predicted to decrease), the impacts should be reviewed anew.

When planning adaptations to the various scenarios identified, it's helpful to refer to Vision 2030, as it provides a comprehensive overview of the vulnerabilities and adaptations associated with the different impacts for various WASH technologies. The most pragmatic adaptation is to develop the resilience of water and sanitation systems – managing risks, building their capacity to deal with unpredictable events and prioritising no-regret measures[9]. These recommendations should be incorporated within a Water Safety Plan, incorporating any other issues and using it as a framework to reduce risks to drinking water from catchment to consumer[27]. The adaptations for Antananarivo, Lusaka and Naivasha were specific to each city, but there were common adaptations which addressed the risk of droughts and flooding, detailed in Table 4.

Table 4 Common adaptations for areas at risk to flooding or drought

	Risk of Water Shortages (droughts)	Risk of Floods
Local Service Provider	- Ensure affordable and accessible water supply - Expand kiosk network into unserved areas - Investigate alternative supplies to use during droughts - Community education and hygiene promotion on the risks to health during droughts	- Community education and hygiene promotion on the risks associated with floods - Education on best practice for latrine construction to prevent latrine collapse and overflowing - Protect boreholes and pipe network from flooding - Regular sanitary inspections during floods - Tighter enforcement against fly tipping - Chlorinate water supply during floods
Utility	- Support the expansion of new kiosks - Build new storage tanks - Investigate the recharge rate/sustainable yield of aquifers	- Leak detection and pipe maintenance - Reduce illegal connections and improve the hydrostatic pressure - Monitoring water quality during floods - Regular inspection of infrastructure during floods
Council	- Engage in water allocation dialogues	- Improve drainage systems: clear and maintain drains, legislation against dumping - Improve solid waste collection - Subsidise tanker/waste disposal options - Land management activities to reduce severity of floods

Beyond the project level, adaptations need to be considered at the governance level, as effective adaptation requires a strengthened planning and implementation process[2]. Governance adaptations identified to adapt to climate change are[7]:

- Mainstream adaptations within the broader development context;
- Strengthen governance and improve water management;
- Improve and share knowledge and information on climate and adaptation measures, and invest in data collection;
- Build long-term resilience through stronger institutions, and invest in infrastructure and in well functioning ecosystems;
- Invest in cost-effective and adaptive water management as well as technology transfers;
- Leverage additional funds through both increased national budgetary allocations and innovative funding mechanisms for adaptation in water management.

TEARFUND[28] identify a 4 step process for incorporating climate change at the policy level which entails:

1. establishing an understanding of the climate risks and key actors;
2. strengthening national policy frameworks;
3. developing and implementing a climate resilient action plan for the water sector;
4. tracking performance and adjusting plans.

In addition, the Water Integrity Network[29] raised concerns about management of future flows of money into the sector and potential corruption. Finally, water providers need to be aware of their carbon emissions, principally the energy required for pumping and should consider alternative energy sources.

Funding

At the project level adaptation to climate change will require additional funding; however, increasing the environmental resilience will positively impact other aspects of the project, improving its sustainability. The funding should be drawn from environmental or management budgets, alternatively new funding can be sourced. Presently the donor community is enthusiastic for funding climate change adaptations, but little money is available from national governments. Typically in developing countries there is limited awareness of climate change outside government (Table 5). Adapting to climate change has clear benefits and the initial investments make sense when considered within projects lifetime as they ensure the' effective running of systems. It is important not to view funding climate change as a separate action but integrate it within environmental and system assessments, being aware that actions need detailed planning and assessment (particularly in areas of water scarcity) since such actions have significant negative tradeoffs and costs[2]. For water and sanitation providers the raised profile of climate change is an opportunity to improve the environmental resilience and the governance of projects which is essential for managing adaptations.

Table 5: Climate change awareness of stakeholders in Antananarivo (Madagascar), Lusaka (Zambia) and Naivasha (Kenya)

Stakeholder	Awareness	Plans/Actions	No. Interviews
Community	Limited	None	30
Local service providers	Limited - Medium	No direct plans	26
Utility	Limited - Medium	No plans - Aware need to adapt system but no direct plans	5
Council	Medium	No direct plans – Council has climate change department	7
Government	Awareness at policy level but little implementation	- Involved in UNFCCC dialogue - Some form of climate change department/networking organisation - REDD - Little regional or district work being completed, seen as issue for central government - Incorporating into policy	19
Researchers	High	Studies being undertaken and advocacy work	3
NGOs	Most have high awareness some limited	- No direct plans - Impact and vulnerability assessments - Set up partnerships/advocacy forums	14
Consultants	Medium	No current projects	2
Local orgs	High	Aware of need to do incorporate the impacts	2

FURTHER RESOURCES

Due to the prominence of climate change there is an abundance of literature. Many of the reports have similar conclusions and they are based on a similar set of references, generally drawing upon the IPCC reports. Predictions of changes to a country's climate are typically based on one or two studies or directly on the IPCC (it is important to trace the original document to determine the resolution of the predictions). Likewise vulnerability assessments are commonly based on limited field data. The following outlines some practical and concise climate change impacts and adaptation resources relevant to this sector:

- CRiSTAL (Community-based Risk Screening Tool – Adaptation and Livelihoods): a tool developed for preparing adaptations to climate change, providing a stepwise methodology for assessing the impacts on livelihoods and identifying adaptations[19]
- DFID WHO Vision 2030 (2010): Evaluates the resilience of water and sanitation technologies to climate change, identifying vulnerabilities and adaptations[1]
- HYOGO: a framework for building the resilience of nations and communities to disasters, includes guiding principles, priorities for action and practical means for increasing reliance; useful to consider alongside work on adaptations[28]
- IRC WASH and Climate Change Group (2010): an ongoing project reviewing the latest research, currently preparing a thematic overview of climate change and WASH and disseminating the latest climate work related to WASH[2]
- ODI Background note: a concise summary of climate change and adaptation[6]
- TEARFUND: a climate change policy overview describing a clear four step process for incorporating climate change into policy at the national level[28]
- Royal Society: A short guide on the science of climate change, highlighting the areas where the science is well established, where there is still some debate and where substantial uncertainties remain[3]
- UNWATER Climate Change Adaptation: an overview of the science of climate change and adaptations at the national level[7]
- USAID: a method for assessing project vulnerabilities to climate change and potential adaptations[16]
- Water Integrity Network: an overview of governance issues that need to be consider when planning adaptations to climate change[29]
- WWF Flowing Forward: The impact of Climate change on freshwater resources[5]

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Appendix I: IWRM Policy Briefing

Policy Brief: When is Integrated Water Resource Management Relevant to WSUP?

Tom Heath, Alison Parker & Keith Weatherhead, Cranfield University 2010

This policy brief outlines whether and when integrated water resource management (IWRM) is relevant to WSUP (Water Supply for the Urban Poor). IWRM is internationally recognised as a good idea, but it can seem to be a confused concept, to both to policy makers and practitioners. It is really a synergy of sustainability, good water management, equity and collaboration, but it is criticised for lacking an operational definition and failing to sustain lasting change. For an overview of IWRM refer to "Pragmatic but Principled"[2] (Heath, 2010[lxxxvii]). This brief reviews the situations when IWRM is relevant to water supply and sanitation services in peri-urban areas, outlines why the process of IWRM is generally not relevant to WSUP then summarises the benefits of incorporating the principles into WSUP's work and how to do this.

IWRM is sometimes relevant to WSUP projects:

- If **there is a localised water resource** (e.g. small aquifer) WSUP need to ensure the local partners understand how they impact the resource and assess its sustainability, setting up management structures to protect the resource, deal with conflict and manage the supply. WaterAid and Oxfam[lxxxviii] have developed a process for community water resource management that can be used as a guide.
- If **water shortages are predicted** for the region, and increasing collaboration and participation will be central to reducing conflict. WSUP should support IWRM processes as the poorest are often the hardest affected, although domestic supplies are generally protected and for large resources WSUP is rarely involved with the resource management. For example in Antananarivo during the dry season there is often insufficient water for irrigation and industry but drinking water supplies are guaranteed
- If WSUP are **capacity building the regulators and the institutions responsible for managing water resources**. They need to encourage them to be proactive in collaborating with all the stakeholders, ensure they engage in IWRM dialogues and get them in contact with the regional Global Water Partnership representative[lxxxix]
- If **WSUP are representing disempowered water users**. WSUP will often be working with marginalised groups who are overlooked or excluded from water resource dialogues. WSUP should engage with these groups to represent their viewpoints, though this will often be done during the implementation of the project. For example WSUP have represented the peri-urban communities in Naivasha (Kenya) during discussions about Lake Naivasha

However, IWRM is often not relevant to WSUP because:

1. **WSUP work with the urban poor** who only require a minimal proportion of the water available and typically have onsite sanitation. Therefore they have little impact on water resources - IWRM can be more relevant for larger utilities who provide large volumes and

[2] Critical review of the background and theory of IWRM, how it is implemented, and how it is relevant to the supply of drinking water and sanitation, urban areas and low income countries.

sewage (domestic demand can be significant during the dry season and wastewater discharges can have a significant impact on water resources)

2. **WSUP aren't mainly involved with the water regulators/managers of the resource.** IWRM focuses upon governments and regulators. The majority of reports are for governments (local and national) and regulators, and there is little information to support IWRM for local water service providers in peri-urban and informal areas. WSUP principally work with utilities and community organisations that usually have their abstractions and discharges managed and determined by other organisations. The exception is localised resources on which the abstractions and discharges for the urban poor may have significant impacts

3. **There is no clear operational definition for IWRM.** The meaning of IWRM is vague, it is described as good water management, but what this actually means in the WSUP context is unclear. Therefore WSUP should focus on doing what they understand as good water resource management, but with more emphasis on collaboration.

4. **It's not an appropriate use of resources.** WSUP are not the appropriate organisation to provide the training or facilitate the process, they don't have experience of IWRM and aren't involved with government level institutions, in addition the benefits to the urban poor would be marginal

5. The benefits of IWRM are fiercely contested; donors are more interested in water safety plans and IWRM reportedly doesn't work in informal settings

In summary, the process of IWRM is generally not very useful to WSUP, but the principles are. The principles have been converted into benchmarks to measure water management and environmental sustainability, developing an audit tool[xc] to assess water resources and project management – the tool emphasises better water management in the slums, not the process of implementing IWRM. This can be used independently, but it will be more effective if incorporated into the WSUP scoping assessment of projects.

For the situations when IWRM is relevant, the most pragmatic approach is to apply "light IWRM", applying the principles at the project level (Heath, 2010). This should bring about meaningful stakeholder participation, community resource management and bring together the key partners to improve the safety of the water. Applying the environmental sustainability audit will help establish a basic framework for addressing the issues. In addition, tools are outlined in Heath 2010 and WSUP should consider implementing Water Safety Plans[xci]. These provide a framework for identifying the risks to the water supply from catchment to consumer and should identify the specific risks to the water supply associated with the above situations. Water Safety Plans are much more relevant to WSUP than exploring any IWRM process, as they specifically address water supply.

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Appendix J: Climate Change Tender

Terms of Reference:

Assessment of how to climate proof water and sanitation services in peri-urban and Informal areas in [city]

1. Background

Water and Sanitation for the Urban Poor (WSUP) is an innovative organization that brings local and global expertise to deliver water and sanitation services to the urban poor. It is a not-for-profit partnership among NGOs, businesses and academia. WSUP has the mandate of supporting local service providers to design and implement water and sanitation solutions that serve the needs of urban poor in developing countries. WSUP supported projects go through four developmental stages – Concept Note; Scoping Study; Development; and Implementation Phase.

A provisional scoping exercise identified [project] in [city] vulnerable to climate variability. To adapt to climate change WSUP are focusing upon increasing the robustness of systems by assessing the impacts of multiple scenarios, including impacts not directly related to water and sanitation, within the context of population pressure, urbanization and environmental degradation. WSUP want to asses the vulnerabilities and the recommendations required to increase resilience and their disaster preparedness.

2. General Objective

The general objective of the assignment is to assess the vulnerabilities of the informal and peri-urban areas of [project] in [city] to climate variability and recommend adaptations to increase the projects reliance to climate variability

3. Specific Objectives

The work is to be divided into three phases:

<u>Phase 1 – Climate Review/Literature Review</u>

- To clarify the current understanding of the changes to climate in [region] and review the impacts of the changes on [region].
    - Contact meteorological department and clarify the changes to temperature, precipitation and extreme events, indicate the degree of certainty associated
    - Synthesize the main climate change reports for the country, identifying the key impacts of climate change on water resources, health, livelihoods and biodiversity
    - Develop a set of plausible (although not necessarily equally likely) scenarios based on the future climate predictions and evaluate the impact on the hydrological cycle, in particular changes to runoff/infiltration

Phase 2 – Vulnerability Assessment/Field Work

- Undertake interviews and focus groups with key stakeholders and members of the community to identify the impacts of the scenarios on the existing environmental, social and economic vulnerabilities and water and sanitation technologies.
    - Summarise the water supply for the [project] including its main components, reliability and sustainability. Summarize the principle causes of water shortages or floods and any information available on water resources, hydrology and hydrogeology
    - Quantify the impacts of floods, droughts, heavy rainfall and other climate events upon the peri-urban and informal communities and assess how vulnerable the communities are to each scenario. The majority of this information will be gained from focus groups with the community
    - Review the significance of the impacts not directly related to water and sanitation on the peri-urban and informal communities
    - Assess the climate change awareness of each of the stakeholders and the plans and actions they have prepared to adapting

Phase 3 – Preparation of Adaptations

- Once the literature review and fieldwork has been completed on the above the Consultant will be required to combine the work into a report, climate proof existing plans and prepare adaptations for improving the projects resilience to climate variability.

    - The impacts of climate on existing plans will be assessed identifying potential risks, vulnerable aspects and priorities for modifications
    - The adaptations will be divided between the local service provider, utility and council dividing the adaptation into short (0-6 months), medium, (6 months to 1 year) and long term (1 year^{+}), dividing them into capital, operation, monitoring and social and economic expenditure
    - Identify key work and ongoing climate change and impact assessment studies

4. Suggested Methodology

Guidance notes have been produced, which overview the methodology, potential resources, and adaptations, including case studies for Antananarivo (Madagascar), Lusaka (Zambia) and Naivasha (Kenya)

- Desk study
- Meet with meteorological organisation to identify key changes
- Facilitation meeting to identify key stakeholders
- 8 – 12 focus groups with community members
- 20 – 30 interviews with key stakeholders
- Direct observation during field visit
- Prepare vulnerability presentation
- Prepare and complete final report

5. Timeframe and level of effort

This consultancy work is expected to require 20 days to be completed within 6 weeks of launching the assignment. However, this can be reviewed at the time of Inception Report.

6. Facilities to be provided by the client.

The client shall introduce the consultant to the community and primary stakeholders such as the [Water Utility], [Council] and [Community organizations]. The client shall also provide the consultant with relevant reports and documents necessary for the assignment.

7. Consultant's staffing.

It is envisaged that as a minimum the key staff in the following disciplines would be required for the assignment:

- Team Leader/Climate change, hydrology expert with knowledge of [city]
- Social data, interview and focus group expert
- Contractual expertise for operation and management of similar WASH facilities

The Team leader would be expected to possess a Masters degree in a relevant field but must demonstrate extensive experience in handling similar assignments in at the least five years. The Team leader must have five year experience working in [city] and have knowledge and access to key stakeholders.

The social data, interview and focus group expert must have at least a first degree in a relevant field and should have had hands on experience of completing interviews, observation and focus groups with the community and stakeholders. He/she should demonstrate extensive experience in handling similar assignments in at the least three years.

The consultant in proposing any other professional must clearly demonstrate the need for such in the team and also state the experience of such a professional.

8. Remuneration

Payment to the consultant shall be scheduled as follows;

- 30% Mobilisation on signing of the contract
- 20% on presentation of the vulnerable peri-urban and informal ares
- 50% on approval of the final report

9. Submission of Proposal

The consultant will submit separate Technical and Financial proposals.

The technical proposal should provide the following amongst others:

1. A brief description of the Consultant or firm and an outline of similar assignments conducted in the last five years.
2. Detailed description of the Consultant's methodology for the assignment
3. The consultant's detailed work plan and schedule for executing the assignment.
4. The Consultant's team for executing the assignment showing various staff and their relevant expertise for the assignment. Current signed CVs.

The Financial proposal should include the following:

1. All costs relevant for the smooth implementation of the assignment.
2. Value Added Tax (VAT)

10. Deliverables

1- Presentation of the vulnerabilities in the peri-urban and informal areas
2- Report detailing how to climate proof water and sanitation services in the informal and peri-urban areas in [city], including the following sections:
    a. Overview of water resources, assessing sustainability if supply and the main causes of floods
    b. Predicted changes to climate
    c. Climate scenarios and their impact on the hydrology
    d. Impacts not directly related to climate change
    e. Impacts of climate change on the informal and peri-urban areas and on water and sanitation technology
    f. Climate change awareness of organisations
    g. Adaptations for Local Service Providers/ climate proof management plans
    h. Adaptations for Utility
    i. Adaptations for Council
    j. Key information and resources

After the presentation on the vulnerability if the client is not satisfied the vulnerabilities have been sufficiently assessed the Consultant should expect to be asked to complete additional fieldwork.

The Consultant should expect to be asked to respond to one round of comments on draft reports before submission of the final reports.

11. Contact:

WSUP………………

Appendix K: Climate Change Concept Note

Project Concept: Climate Proofing Water and Sanitation Services

WSUP
Water & Sanitation
for the Urban Poor

Executive Summary

This project concept sets out a request for funding for an 18 month project through which Water & Sanitation for the Urban Poor (WSUP) will mainstream climate change in their work and identify how to climate proof water and sanitation services in the seven cities where WSUP is already supporting projects. This will entail incorporating climate change into the WSUP strategy, assessing local vulnerabilities and identifying potential adaptations for the local service providers and local authorities, trialling low cost adaptations identified in three previously completed pilot studies, capacity building for municipalities and local government and preparing proposals to implement the adaptations required to climate proof supplies and services in each of the cities. The total funding required is $250,000.

Background

Climate change is expected to exacerbate current stresses on water resources, due to changes in average rainfall, temperature and the frequency and magnitude of extreme events. Water is at the root of climate vulnerability, as changes to the hydrological cycle can cause floods, water shortages droughts, decreased water quality and less predictable weather. This makes it difficult to manage water resources affecting the function and operation of existing water infrastructure, impacting food availability, urbanisation and the livelihoods and well-being of societies.

WSUP were aware that climate change posed potential risks to the projects that they support, but were uncertain how or where the impacts would be experienced. To address this WSUP commissioned a 10 month study in 2010 with Cranfield University to assess the opportunities and vulnerabilities of climate change for WSUP supported projects. The study entailed quantifying the potential changes to climate and the impacts this may have on each country, assessing a city's vulnerability to floods and droughts, and establishing scenarios to assess how the changes would impact the hydrology and affect the project deliverables. Adaptations were then identified to climate proof water and sanitation services for the local service provider, water utility and local municipality. The research was based on a literature review (including DFID's Vision 2030 study) and three pilot studies in Antananarivo (Madagascar), Lusaka (Zambia) and Naivasha (Kenya)[1] which involved focus groups, stakeholder interviews and observations. This concept note is based upon the findings of this research which drew the following conclusions[2]:

- For water and sanitation providers climate change will tend to exacerbate or relieve existing vulnerabilities rather than create new issues.
- The main risks are from changes to the frequency and magnitude of flooding and droughts,
- The impacts must be considered within the context of population growth, urbanisation and environmental degradation.
- To adapt to climate change water providers should not consider climate change in isolation, but rank and prioritise it against other sources of risk and uncertainty, focusing on increasing the environmental resilience and disaster preparedness of projects.

[1] The climate proofing reports for each of the pilot studies are available at www.wsup.com/sharing/Resources.htm

[2] Heath, T., Parker, A., & Weatherhead, K. (2010), How to climate proof water and sanitation services. Report prepared by Cranfield University. WSUP, London. Available at www.wsup.com/sharing/learning.htm

WSUP now intends to apply this research in a practical form to increase the environmental resilience of the projects they support, incorporate climate change into future plans and prepare proposals to ensure that their programme is robust. This will entail scaling up the processes developed during the research for the projects in the first three cities to ensuring the vulnerabilities are understood, trialling some of the low cost options and integrating climate change within WSUP's planning and engagement with communities and service providers. The main outcomes will be funding proposals for each project to enable them to implement the recommended adaptations in the three existing and four future vulnerability assessments. The project locations are Antananarivo, Lusaka and Naivasha, as mentioned above, and Dhaka, Kumasi Maputo and Nairobi.. Adapting to climate now will significantly increase the long term cost-effectiveness of projects by ensuring they are resilient to climate variability, which if left unchecked has the potential to undermine the sustainability of current efforts to improve water and sanitation services.

Project Description

The GOAL for the 18 month project is:

To improve environmental resilience within the 7 project locations identified above.

The OUTCOMES of the project will be:

a) A detailed climate change strategy developed for all new projects
b) An understanding of how each of the seven cities is vulnerable to climate change and the adaptations required to climate proof their water and sanitation services.
c) Low cost flood and drought adaptations trialled in three cities
d) Increased climate understanding and developed capacity within Local government and municipalities
e) 7 climate proofing proposals prepared (one for each WSUP location)

Specific Objectives and Proposed Activities

SO1. Integrate climate change into WSUP planning

- To integrate considerations of climate change into WSUP project planning and development, for example by incorporating a rapid screening process into the project scoping phase.

Activity 1. Development of strategy to integrate climate change into WSUP planning and development. The strategy will link directly to existing concept, scoping and development phases of project development

SO2. Assess the impact of climate change on 7 cities in Africa and South Asia.

- To asses if existing WSUP supported projects are sensitive to climate change by completing a climate change assessment to identify the likely changes to climate and vulnerability within the project city.

Activities 2. Collect key climate resources and contact meteorological organisation to clarify climate changes
3. Assess project's sensitivity to climate change

- To undertake an assessment of the vulnerabilities within the 4 remaining cities to climate variability and recommend adaptations to increase resilience to such variability, including climate proofing any existing plans

Activities 4. Identification of potential consultants with required expertise
5. Distribute key resources and reports to selected consultant
6. Arrange interviews with key stakeholders, focus groups and community for consultant
7. Evaluation of consultants vulnerability assessment presentation
8. Feedback on 1st draft of vulnerability assessment report

SO3. Trial appropriate adaptations to floods and droughts in pilot projects

- To design and implement selected low cost adaptations to floods and droughts identified for the vulnerable communities from the three pilot studies (refer to table for examples)
- To review the effectiveness of each of the adaptations implemented and the potential to scale up and incorporate them into city wide programmes

These activities will be implemented by the local service providers with financial and technical support from WSUP:

Local Service Provider in communities at risk to floods (Antananarivo & Lusaka)

9. Train 5 hygiene promoters on the risk to health during floods and best practice on construction of latrines
10. Community education raising focusing on key hygiene messages and hygiene competitions
11. Construction of borehole flood protection
12. Establish team to undertake sanitary inspections during floods
13. Train attendants to chlorinate at point of distribution during floods

Water Utility in communities at risk to floods (Antananarivo & Lusaka)

14. Establish a programme for leak detection and reducing illegal connections
15. Regular monitoring of non revenue water
16. Establish team to monitor water quality during floods
17. Establish team to inspect infrastructure during floods

Local Service Provider in communities at risk to droughts (Naivasha & Lusaka)

18. Train 5 hygiene promoters on the risk to health during droughts
19. Community awareness raising focusing on key hygiene messages
20. Detailed baseline household survey of water supply affordability and accessibility during droughts

Water in communities at risk to droughts (Naivasha & Lusaka)

21. Advice and guidance on how to investigate the recharge rate/sustainable yield of aquifers

Scaling Up

22. Assessment of the adaptations trialled using community interviews and focus groups

SO4. Capacity building of service providers

- To initiate dialogues within local water utilities and municipalities on how to incorporate climate change into their work

Activities
23. Distribute vulnerability assessment to stakeholders and promote discussion on the risks of climate change
24. Identify staff from local service provider and water utility to send on climate training course

- To promote climate proofing dialogue with local government and regulators in order to help them to develop policy and guidelines

Activities
25. Assessment of current climate change policy and plans

Advice and guidance on improving climate change resilience

- To develop climate change resources for the sector on climate proofing water and sanitation services for the urban poor.

26. Document and publish climate proofing work online
27. Publish academic papers on research

SO5. Proposals for climate proofing

- Prepare proposals to implement the adaptations identified during the climate proofing and vulnerability assessments on a city wide basis for the water utility and or city authorities for each of the 7 cities.

28. Consultation with Local Service Provider and Water Utility to identify priority adaptations and agree plan for adaption
29. Preparation of DFID proposal to implement adaptations by WSUP local staff and country director

Application to each of 7 cities

The table below provides an overview of how the specific objectives will be applied to each of the target cities. The numbers refer to the proposed activities detailed above:

Specific Objective	Project Location						
	Antananarivo	**Lusaka**	**Naivasha**	**Nairobi**	**Dhaka**	**Kumasi**	**Maputo**
1. Integrate climate change into WSUP planning	Integrate climate change into project development, principally this will be the responsibility of the WSUP secretariate [1]						
2. Assess the impact of climate change	*NB - Assessments have already been completed by Cranfield University under the first phase*			Screening complete [5-9]	Undertake climate proofing assessment [3-4]		
3. Trial common simple adaptations to floods and droughts in pilot projects	**Local Service Provider** Floods - Community education and hygiene promotion on the risk to health during floods [10] - Education on best practice of latrine construction [11] - Protect borehole from flooding and intense rainfall [12] - Sanitary inspections during floods [13] - Chlorinate water during floods [14] Droughts - Community education and hygiene promotion on the risk to health during droughts [19-20] - Ensure affordable and accessible water supply during droughts [21]			If measures are successful either scale up to other projects, alternatively incorporate into climate proofing proposal [10-23]			
	Water Utility Floods - Leak detection [15 -16] - Reduce illegal connections [15 -16] - Monitor water quality during floods [17] - Regular inspection of infrastructure during floods [19] Droughts - Investigate the recharge rate/sustainable yield of aquifers [22-23]						
4. Capacity building of service providers	- WSUP local staff to collect response to climate proofing assessment [24] - Increase climate change understanding of providers [25] - WSUP to determine key climate change policy and engage in stakeholder forums [26-27] - Distribute key resources to sector (Government, NGOs and Academic) [28-29]						
5. Proposals for climate proofing	Convert climate proofing summary into proposal [30-31]	Prepare climate proofing proposal based on vulnerability report [30-31]	Prepare climate proofing proposal based on vulnerability report [30-31]	Prepare climate proofing proposal once vulnerability report is complete [30-31]			

Other essential activities

Project Management

30. Support from Project Directors
31. Baseline survey at outset of current climate change knowledge awareness and practice within local service providers
32. Support from WSUP Secretariat

Resource requirements

A summary of the budget is outlined below. All figures are US Dollars.

Component	
Integrate Climate Change into WSUP planning	$5000
Assess the impact of climate change on WSUP's priority projects	$10,000
Trial common simple adaptations to floods and droughts in pilot projects	$150,000
Antananarivo	$50,000
Lusaka	$50,000
Naivasha	$50,000
Capacity building of service providers	$45,000
Climate proof proposals	$10,000
Project management	$30,000
Total	$250,000

WSUP is requesting a total of $250,000 in order to fund activities to be carried out during the 18 month project period. The funding includes the preparation of the 7 new climate proofing proposals, but it does not include the cost of implementing them. Additional funding will be sought from donors or other funding sources for the new proposals. The estimated cost for the full proposals in the seven target cities is approximately US $1 million.

Prepared December 2010

Appendix L: Interview and Focus Group Guides

8 Community Focus Groups

Focus groups are an excellent method for gaining a large amount of information and assessing the significance and scale of the issue and overview what is being done to adapt

Familiarisation
Start by each participant introducing themselves, how long they have lived in the area, their age, family, and livelihood.

Start-up

Welcome the participants. Explain to them that you want to understand from this session i.e. impact of flooding/droughts on their life and livelihoods. Explain that you also want to understand causes and effects of such impact on their lives. You also want to discuss the solution of such causes of flooding/droughts.

Background

- What is the impact of heavy rains/do you get floods/droughts/cyclones
- When was the last event, how often do they occur, how much warning did you get, how long did it last, have you seen a change in the frequency/nature, was it different from last time?

Impacts

Discuss the impacts of droughts and flood on the community. Possible questions include:

- How do they impact livelihoods/jobs?
- How do they impact education?
- How do they impact water supply (location, reliability, use)?
- How do they impact toilets?
- How do they impact buildings?
- How do they impact health?
- Is there more of an impact on women/men?
- How do they impact prices (food, charcoal)?
- How do they affect the community as a whole?
- Do you have any other problems/ cause/impact?
- What is the biggest impact/How much of a problem is it?

Adaptations

- What is the best way to tackle each of the causes of the vulnerability or impact of flooding/drought?
- Who is responsible for this to solve? What role they want to see local government, CBOs, NGOs playing to solve the problem?
- What are they doing? Why are they not doing?
- What poor people can do by themselves? What capacity do they have? What support they expect from local government? How can WSUP help them?

9 Community

Background

1. What is your name
2. How long have you lived in the area/ why did you come here?
3. How is life here?
4. Where do you get your water?
    a. how much do you pay
    b. Do you have 24/7 supply
    c. how far/time/variation in season/reliability/problems
    d. Are there enough kiosks
    e. Where do people get water
    f. Is there much vandalism
5. Where do you go to the toilet?
    a. What is it made from
    b. How did you decide the design
    c. Are there communal latrines/would people pay
    d. What to the poorest do
    e. Any open defecation
    f. When it's full what do you do/emptying options
    g. Is there enough space for new latrines
    h. How deep is the water (does it vary)
6. How often do you buy soap?
    a. What do you use It for
7. Have you been taught about hygiene?
    a. When, by whom how often

Vulnerability of community

8. What are the main problems here?
    a. Where does the water goes once its drained
    b. What do you do with rubbish

Climate Change Awareness

9. Have you heard of climate change?
    a. What is it about/what are the impacts
    b. Where did you find out about it

Impacts of climate events (Floods, droughts, change in rainy season – short/longs)

10. What is the impact of heavy rains
    a. Do you get flooding when they are very heavy
11. Have you been affected by floods/droughts/cyclones
    b. How often (number a year)
    c. Did it come suddenly/what was the extent
    d. What did you do when the water started coming/dried up
    e. How long did it last
    f. Have you seen a change in patterns (indicator)
    g. Was it different from last time
12. How did it impact your household?
    a. How did it affect your livelihood/education/ food shortages
    b. Are there more demands on women
    c. How did it affect your health
    d. How did it affect buildings
    e. How did it affect your water supply (location, reliability, use)
    f. How did it affect your toilet
13. How does it affect the community as a whole?
14. Do you have any other problems/ cause/impact

Repeat for each event

Adaptations

15. What needs to be done to reduce the problems
16. What do you do to protect your home facilities?
17. How would change the design of water supplies?
18. How would change the design of latrines?
19. Has it changed how you plan for the future?
20. Where do you go for help, what was the role of the council and water supplier/what support do you get?
21. What could the community do to reduce the impact of the problem?
22. What could the service provider/council/government do to reduce the vulnerability?

Indirect Impacts of climate change

23. What is the price of stable food (maize, livestock, charcoal)?
    a. how much does it change during seasons
    b. What about floods/droughts
    c. What is the effect
24. How does the price of electricity vary
25. Has the population change is there much migration/what is the impact?
26. How does employment vary during the year – flower farms /irrigation?
27. Who else should I talk to?

10 Community Organisation

Background

1. Where is your water abstracted?
    a. Is there continuous supply/does it vary with season/how does the level change
    b. Multiple sources
    c. Do you have any problems with quality/what treatment is required
2. What are the main elements of supply?
    a. Do you have plans for expansion
    b. Is your water pressurized 247
    c. Are you continuously pumping
3. What is the demand for water
4. How much water do you supply and what is the coverage?
5. What is the sanitation situation
    a. Type/coverage/ability to build/OD
6. What are the main barriers to supply water
7. What tariff structure do you operate?
8. Who are the main organisations?
9. What is your main challenge?
10. Any other problems

Climate Change Awareness

11. Have you heard of climate change?
    a. What is it about
    b. Where did you find out about it
    c. What are the impacts on abstractions and demand
    d. How are you taking it into account

Impacts and Adaptations of Events (Floods/Droughts/heavy rains)

12. What would be the impact of increased rains
13. Are you affected by: flooding/high ground water levels/heavy rainfall /runoff/droughts /low ground water?
14. When was the last flood/drought, how long did it last/what was the extent?
15. How does it impact the community?
    a. Livelihoods/health/business
16. How did it impact your system? (explore each action in detail)
    b. Water supply/quality
    c. Kiosks
    d. How is demand affected
    e. Pipes
    f. Sanitation
    g. Takings

Repeat for each event

Adaptations

17. How do you adapt?
    h. Technical solutions
    i. Social solutions
    j. Maintenance
18. What would solve the problems/ what adaptations do you suggest?
19. How could the utility/council/government adapt
20. What support do you get?

Vulnerability of community

21. Are there are any other problems for the community?
22. What is the community most vulnerable to?

Water Resources

23. Are there any bridges or trunk mains over main rivers at risk of flooding?
24. Is any infrastructure at risk to landslides?
25. Is there a risk of water becoming saline?
26. How does the river vary
27. What are the main abstractions
28. What is the depth of the groundwater
29. What are the main abstractions?
30. What factors impact them?
31. What would be the impact of declining levels?
32. How are they affected by climate change?
33. Who is responsible for managing the resources?
34. Is your abstraction sustainable?
    a. Including future growth/ CC

Maintenance (short/medium/long term)

35. Do you have a maintenance plan or equivalent?
36. What capital expenditure do you have planned?
    a. Deal with floods/droughts
    b. Adapt to climate variability
    c. Adapt to climate change
37. What are your operational costs?
    a. How is this likely to change
38. What maintenance are you currently undertaking?
    a. Extent of problems
    b. Availability of spares
    c. Number of days spent dealing with problem/number of staff
    d. Future (variability/CC)
39. What are your current social and economic programmes?
    a. Future (variability/CC)

11 Utility

Background

1. Where is your water abstracted?
   a. Is there continuous supply/does it vary with season/how does level change
   b. Multiple sources
   c. Do you have any problems with quality/ treatment required
2. How much water do you supply and what is the coverage?
3. What about in the peri-urban areas
4. What is the sanitation situation- Type/ coverage
5. What are the main barriers to providing water and sanitation?
6. What tariff structure do you operate?
7. Who are the main organisations?
8. What is your main challenge

Climate Change Awareness

9. Have you heard of climate change?
   a. What is it about
   b. Where did you find out about it
   c. What changes to climate are expected
   d. What will be the impact of climate change
   e. What are the impacts on abstractions and demand
   f. How are you taking it into account as an organisation

Impacts and Adaptations of Events (Floods/Droughts/changes to seasons)

10. What would be the impact of increased rains
11. What would be the impact increased temp changed/droughts?
12. Are you affected by: Flooding/high ground water levels/heavy rainfall/runoff/droughts/low ground water levels?
13. When was the last/ how long did it last/ what was the extent?
14. How does it impact the Local provider?
    a. Water supply/quality
    b. Kiosks
    c. How is demand affected
    d. Pipes
    e. Sanitation
    f. Gender
15. What other problems are there?
    Repeat for different event

Adaptations

16. How do you adapt?
    a. Technical solutions
    b. Social solutions
    c. Maintenance
17. What support do you get?
18. What would solve the problems/ what adaptations do you suggest?
19. How could the council/government/NGO adapt

Water Resources

20. Are there any bridges or trunk mains over main rivers at risk of flooding?
21. Is any infrastructure at risk to landslides?
22. Is there a risk of water becoming saline?
23. How does the river vary
24. What are the main abstractions
25. What is the depth of the groundwater
26. What are the main abstractions?
27. What factors impact them?
28. What would be the impact of declining levels?
29. How are they affected by climate change?
30. Who is responsible for managing the resources?
31. Is your abstraction sustainable?
    b. Including future growth/ CC

Maintenance (short/medium/long term)

32. Do you have a maintenance plan or equivalent?
33. What capital expenditure do you have planned?
    a. Deal with floods/droughts
    b. Adapt to climate variability
    c. Adapt to climate change
34. What are your operational costs?
    a. How is this likely to change
35. What maintenance are you currently undertaking?
    a. Extent of problems
    b. Availability of spares
    c. Number of days spent dealing with problem/number of staff
    d. Future (variability/CC)
36. What are your current social and economic programmes?
    b. Future (variability/CC)
37. Long term/large project plans?

38. Who else should I speak to?

12 Municipality/Council

Climate Change Awareness

1. Have you heard of climate change?
    a. What is it about
    b. Where did you find out about it
    c. What changes to climate are expected
    d. What will be the impacts
    e. How are you taking it into account as an organisation

Impacts of Events (Floods, Droughts, changes to seasons)

2. What would be the impact if rainfall increased
3. What would be the impact if temperatures increased
4. How are the peri-urban areas affected by floods/droughts/seasonal changes?
5. When was the last/ how long did it last/ what was the extent?
6. How does it impact the community?
    a. How does it affect livelihoods/education/lost days work/school/food shortages
    b. How does it affect health
    c. How does it affect water supply (location, reliability, use)
    d. How does it affect sanitation
    e. How is gender affected
    f. How does it affect hygiene
    g. How does it affect drainage/waste collection
7. What other problems are there

Repeat for different event

Adaptations

8. How does the community adapt?
    h. Technical solutions
    i. Social solutions
    j. Maintenance
9. How are you as organisation adapting?
    a. Technical solutions
    b. Social solutions
    c. Maintenance
10. How do you fund adaptations- is there sufficient funding?
11. What technical support do you get from other organisations?
12. What would solve the problems/ what adaptations do you suggest?

Impact of climate change on indirect aspect

13. What are the other impacts of the floods/droughts/intensity?
    a. What is the impact on agriculture/livestock?
    b. Do food prices vary?
    c. Does migration change?
    d. How is electricity impact

Repeat for different event

Vulnerability of community/peri/-urban areas

14. Are there are any other problems for the community?
15. What is the community most vulnerable to?

Water Resources

16. Are there any bridges or trunk mains over main rivers at risk of flooding?
17. Is any infrastructure at risk to landslides?
18. Is there a risk of water becoming saline?
19. How does the river vary
20. What are the main abstractions
21. What is the depth of the groundwater
22. What are the main abstractions?
23. What factors impact them?
24. What would be the impact of declining levels?
25. How are they affected by climate change?
26. Who is responsible for managing the resources?
27. Is your abstraction sustainable?
    c. Including future growth/ CC

Maintenance (short/medium/long term)

28. Do you have a maintenance plan or equivalent?
29. What capital expenditure do you have planned?
    a. Deal with floods/droughts
    b. Adapt to climate variability
    c. Adapt to climate change
30. What are your operational costs?
    a. How is this likely to change
31. What maintenance are you currently undertaking?
    a. Extent of problems
    b. Availability of spares
    c. Number of days spent dealing with problem/number of staff
    d. Future (variability/CC)
32. What are your current social and economic programmes (Future (variability/CC)?
33. Long term/large project plans?

Studies being done/Research

34. What studies and research are being done on water resources, water balances or CC?
35. Key contacts, who else should I talk to?

13 Government

Expected Changes to climate

1. What are the changes expected to climate
2. What will be the impact of changes to
    a. Temperature
    b. Rainfall
    c. Extreme events

Climate Change Awareness

1. How aware of climate change is the government?
2. How is the government preparing for climate change
3. How is climate change monitored
4. How much has climate change been incorporated into policy?
5. How are you planning to fund adaptations
6. Who are main institutions researching climate change?

Impact of Climate change on indirect aspect

7. How will electricity generation be impacted?
8. How will agriculture and livestock be impacted?
9. How will migration be impacted?

Water Resources

10. What is the state of water resource in the country?
11. Who is responsible for managing water resources?
12. What are the main challenges for water resources?
13. Are current abstractions sustainable?

Studies being done/Research

14. What studies and research are being done on water resources, water balances or climate change?
15. Who are the key contacts, who else should I talk to?

14 NGOs/Researchers

Climate Change Awareness

1. How aware of climate change is the government?
2. How much has climate change been incorporated into policy?
3. Who are main institutions researching climate change?
4. How are you taking climate change into account as an organisation?
5. What are the impacts of climate change

Expected Changes to climate

6. What are the changes expected to climate
7. How is the climate expected to change
    a. Temperature
    b. Rainfall (seasonality, impact of short rains shorter)
    c. Extreme events
    d. ENSO

Impacts of Events (Floods, Droughts, changes to seasons)

8. What would be the impact if rainfall increased
9. What would be the impact if temperatures increased
10.
11. Are the peri-urban areas affected by: flooding/high ground water levels/heavy rainfall/runoff/droughts/low ground water levels?
12. When was the last/ how long did it last/ what was the extent?
13. How does it impact the community?
    k. How does it affect livelihoods/education/lost days work/school/food shortages
    l. How does it affect your health
    m. How does it affect water supply (location, reliability, use)
    n. How does it affect sanitation
    o. How does it impact gender
    p. How does it affect hygiene
    q. How does it affect drainage/waste collection
    r. What other problems are there

    Repeat for different event

Adaptations

14. How does the community adapt?
    s. Technical solutions
    t. Social solutions
    u. Maintenance
15. How are you as organisation adapting?
    a. Technical solutions
    b. Social solutions
    c. Maintenance
16. What technical support do you get from other organisations?
17. What would solve the problems/ what adaptations do you suggest?
18. How would you change the design on latrines and water sources?

Impact of climate change on indirect aspect

19. What are the other impacts of the floods/droughts?
    a. What is the impact on agriculture/livestock?
    b. Do food prices vary?
    a. Does migration change?
    b. How is electricity impact

Vulnerability of community/peri/-urban areas

20. Are there are any other problems for the community?
21. What is the community most vulnerable to?

Water Resources

22. Are there any bridges or trunk mains over main rivers at risk of flooding?
23. Is any infrastructure at risk to landslides?
24. Is there a risk of water becoming saline?
25. How does the river vary
26. What are the main abstractions
27. What is the depth of the groundwater
28. What are the main abstractions?
29. What factors impact them?
30. What would be the impact of declining levels?
31. How are they affected by climate change?
32. Who is responsible for managing the resources?
33. Is your abstraction sustainable?
    d. Including future growth/ CC

Studies being done/Research

34. What studies and research are being done on water resources, water balances or climate change?
35. Who are the key contacts, who else should I talk to?

Identify which of the following risk will be a problem:

36. Increased risk of flooding
37. Increase in ground water recharge
38. More extreme rainfall
39. Increase runoff